Of the 1913 *edition of the Book of Standards this is copy No.* 9596

Book *of* Standards

Containing Tables *and* Useful Information Pertaining to Tubular Goods as Manufactured by

National Tube Company

Pittsburgh, Pa.

Price, Two Dollars

NATIONAL TUBE COMPANY

Pittsburgh, Pa. Nineteen Hundred and Thirteen

AMERICAN BANK NOTE COMPANY, NEW YORK AND PITTSBURGH

National Tube Company

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CORRECTION SHEET No. 1

FOR 1913 EDITION

NATIONAL TUBE COMPANY

BOOK OF STANDARDS

This correction sheet embraces and supersedes all previous correction sheets.

Items marked with an asterisk (*) have not been included in previous sheets.

Please make notation of changes in Book and insert this sheet in tape in back of Book of Standards.

NOTE

Our records indicate that 1913 Edition Book of Standards

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This correction sheet is being mailed to same address. We should be notified of any change of address.

***Page 35.**—South Penn Casing $5\frac{3}{16}''$ size 17 pounds, coupling data reads as follows:

Diameter 6.050″
Length 4⅝″
Weight 6.759 pounds

This should be changed to read as follows:

Diameter 6.155″
Length 5⅛″
Weight 8.849 pounds

*South Penn Casing 6⅝″ size 20 pounds, coupling data reads as follows:

Diameter 7.642″
Length 5⅛″
Weight 11.133 pounds

This should be changed to read as follows:

Diameter 7.699″
Length 6⅛″
Weight 14.458 pounds

NATIONAL TUBE COMPANY

FRICK BLDG., PITTSBURGH, PA.

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PREFACE

In this edition of our handbook, which is much larger than those preceding, it has been our aim to give all the dimensions and data pertaining to tubular goods as manufactured by National Tube Company, at this date.

We have incorporated in the book certain subjects, closely related to the uses of pipe and tubes and have given such general information and engineering data as pertains to the same. In compiling the engineering data we have relied entirely on the engineering authorities as quoted in the text. We have also added a glossary of terms relating to the pipe and fittings trade which will, no doubt, be found of much value to the users of pipe and fittings.

STANDARD PROCESSES AND MATERIALS USED IN THE MANUFACTURE OF TUBULAR GOODS

INTRODUCTION

To many users of tubular goods the processes of manufacture, properties and characteristics of the metal, and indeed, the possibilities of modern welded tubes and pipe are more or less unknown. We, therefore, present in this chapter information on these subjects, in a style as free from technical detail as possible, so that the consumer may know more about the material he is using, and benefit by the experience and practice of others. In order to limit this chapter to reasonable space, it is necessary to confine ourselves to an outline of the more important methods and materials used in the manufacture of tubular goods of to-day.

The development of the steel-pipe industry has been phenomenal during the past nine years, as evidenced by the increase in the output of the National Tube Company from 416 064 tons in 1900 to 1 013 071 tons for the year 1909. The main factor in this great expansion has been the development of a satisfactory quality of soft weldable steel as a substitute for wrought iron; the grade of steel made exclusively for this purpose by us to-day has been proved, in all points, superior to the wrought iron of days gone by. By comparing the properties and characteristics of wrought iron with those of pipe steel, as made under our process, we believe the reader will readily understand why this steel has become the standard material for the manufacture of welded tubes and pipe.

All tubular goods are manufactured by one of two general processes: either by shaping sheets of metal, termed skelp, into tubes and welding the edges together; or by forming or drawing the tubes from solid billets or plates of metal. The products of the various processes are termed respectively "welded" or "seamless."

WELDED TUBES AND PIPE

Welded tubular goods are made either by the lap- or butt-weld process.

Lap-weld Process. The skelp used in making lap-welded tubes is rolled to the necessary width and gage for the size tubes to be made, the

edges being scarfed and overlapped when the skelp is bent into shape, thus giving a comparatively large welding surface, compared with the thickness of the plate (see Fig. 1). As a result of the work done in forging down the metal at the weld, tubes made in this way will probably be stronger at the weld than at any other place.

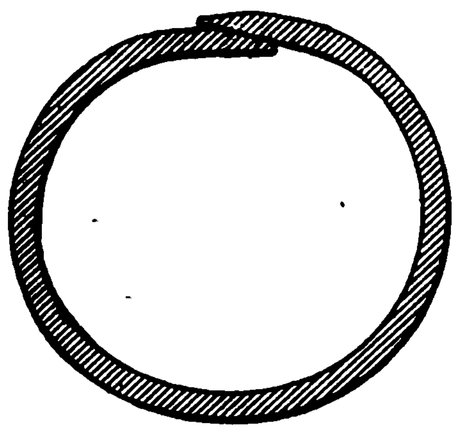


Fig. 1. Lap-weld

The skelp is first heated to redness in a "bending furnace," and then drawn from the front of the furnace through a die, the inside of which gradually assumes a circular shape, so that the skelp when drawn through is bent into the form of a tube with the edges overlapping as shown in Fig. 1.

In the next operation the skelp so formed is heated evenly to the welding temperature in a regenerative furnace. When the proper temperature is obtained, the skelp is pushed through an opening in the front of this furnace into the welding rolls, passing between two rolls set one above the other, each having a semicircular groove, so that the two together form a circular pass. Between these rolls a mandrel is held in position inside the tube, the lapped edges of the skelp being firmly pressed together at a welding heat between the mandrel and the rolls. The tube then enters a similarly shaped pass to correct any irregularities and to give the outside diameter required. It will be noted that the outside diameter is fixed by these rolls; any variation in gage, therefore, makes a proportional variation in the internal diameter. This also applies to butt-weld pipe. Finally, the tube is passed to the straightening, or cross rolls, consisting of two rolls set with their axes askew. The surfaces of these rolls are so curved that the tube is in contact with each for nearly the whole length of the roll, and is passed forward and rapidly rotated when the rolls are revolved. The tube is made practically straight by the cross rolls, and is also given a clean finish with a thin, firmly adhering scale.

After this last operation the tube is rolled up an inclined cooling table, so that the metal will cool off slowly and uniformly without internal strain. When cool enough the rough ends are removed by cold saws or in a cutting-off machine, after which the tube is ready for inspection and testing.

In the case of some sizes of double-extra-strong pipe (3 in. to 8 in.) made by the lap-weld process, the pipes are first made to such sizes as will telescope one within the other, the respective welds being placed opposite each other; these are then returned to the furnace, brought to the proper heat, and given a pass through the welding rolls. While a pipe made in this way is, in respect to its resistance to internal pressure, as strong or stronger than when made from one piece of skelp, it is not necessarily welded at all points between the two tubular surfaces; however, each piece is first thoroughly welded at the seam before telescoping.

Butt-weld Process. Skelp used in making butt-welded pipe comes from the rolling department of the steel mills with a specified length, width, and gage, according to the size pipe for which it is ordered. The edges are slightly beveled with the face of the skelp, so that the surface of the plate which is to become the inside of the pipe is not quite as wide as that which forms the outside; thus when the edges are brought together they meet squarely, as indicated in Fig. 2.

The skelp for all butt-welded pipe is heated uniformly to the welding temperature, in furnaces similar in general construction to those used in lap-welding. The strips of steel when properly heated are seized by their ends with tongs and drawn from the furnaces through bell-shaped dies, or rings. The inside of these dies is so shaped that the plate is gradually turned around into the shape of a tube, the edges being forced squarely together and welded. For some sizes the pipes are drawn through two rings consecutively at one heat, one ring being just behind the other, the second one being of smaller diameter than the first.

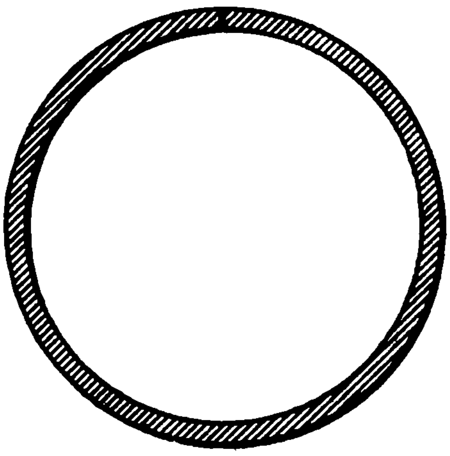


Fig. 2. Butt-weld

The pipes are then run through sizing and cross rolls similar to those used in the lap-weld process, obtaining thereby the correct outside diameter and finish.

The pull required to draw double-extra-strong (hydraulic) pipe by this process is so great, on account of the thickness of the skelp, that it is found necessary to weld a strong bar on the end of the skelp, thereby more evenly distributing the strain. With this bar the skelp is drawn through several dies of decreasing size, and is reheated between each draw until the seam is thoroughly welded. It is evident that the skelp is put to a severe test in this operation, and, unless the metal is sound and homogeneous, the ends will almost always be pulled off.

Properties of Materials. Experience has developed a grade of soft steel (which would more properly be called highly refined iron) especially adapted to the manufacture of welded pipe. Uniformity and homogeneity of composition mean satisfactory welding practice and small scrap losses in manufacture, as well as a better quality of product for all purposes. This has been our aim for years, to accomplish which it has been found absolutely essential to control the manufacture of the metal from the ore to the finished tube or pipe. The practice of the National Tube Company is to make tube and pipe steel exclusively; thus by concentrating the attention of a highly trained force of men on this one grade of metal, the best results can be attained. This steel is made by the Bessemer or Basic Open-hearth process, according to the use to which it is to be put, and will *average* in chemical and physical properties as follows:

	Chemical analysis				Physical pulling tests			
	Carbon	Manganese	Sulphur	Phosphorus	Elastic limit	Tensile strength	Elongation in 8 ins.	Reduction in area
	%	%	%	%	Pounds	Pounds	%	%
Bessemer pipe steel..	.07	.30	.045	.100	36 000	58 000	22	55
Open-hearth pipe steel	.09	.40	.035	.025	33 000	53 000	25	60

In ductility this steel excels any material heretofore used in the manu'acture of pipe. For bending into coils, or the various shapes required n electric conduit work, steel pipe is especially adapted. In this work t has given most satisfactory results; similarly, for boiler tubes or ›ther purposes, where the metal has to stand cold flanging or other ›evere manipulation.

Welding and Annealing. Good welding quality is of prime impor:ance in pipe steel, and is sought after and maintained by a system of :areful inspection. This not only is an assurance that the seam will be ›trong and reliable, but is a quality highly desired in the shop where tubes ›r pipes have to be welded to each other, or to other material.

The welding heat naturally produces a larger grain in the metal. This ›loes not necessarily mean loss of ductility, but, where a large margin of ›afety against failure by shock is desired, the grain may be refined by ınnealing. The method giving best results, is to heat the steel to a ›right orange color in shop light (1750° F.) for a few minutes, allowing :he piece to cool in the air — very slow cooling is not necessary. So :reated, the fracture of the metal should show a fine silky texture with›ut any trace of crystallization.

Threading. To insure a good threaded joint between a pipe and a itting, it is necessary to have a clean, smoothly cut thread. To cut this ‹ind of a thread, it is necessary to have a good die, which consists of a 'rame or holder and a set of chasers made with proper consideration for :he following points: — lip, clearance, chip space, lead, and number of :hasers.

Lip, which is also known as *hook* or *rake*, is the inclination of the :utting edge of the chaser to the surface of the pipe, as shown in Fig. 3. This lip may be secured by milling the cutting face of the chaser, as ›hown by the full lines, or by inclining the chaser, as shown by the dotted ines. This lip angle should be from 15° to 25°, depending upon the style ınd condition of the chasers and chaser holders.

Clearance. Clearance is the angle between the thread of the chasers ınd the threads of the pipe. This clearance may be secured in various ways, depending upon the position in which the chasers are held in the 'rame. The position of the cutting edge of the chaser in relation to the :enter line of the pipe while working, determines whether the chasers

shall be set "in" or "out" while the teeth are being machined, as shown in Figs. 3 and 4.

Chip Space. This is the space required in the holder in front of the chaser to allow room for the accumulation of chips, and also to provide means for lubricating the chasers. This space should be secured as

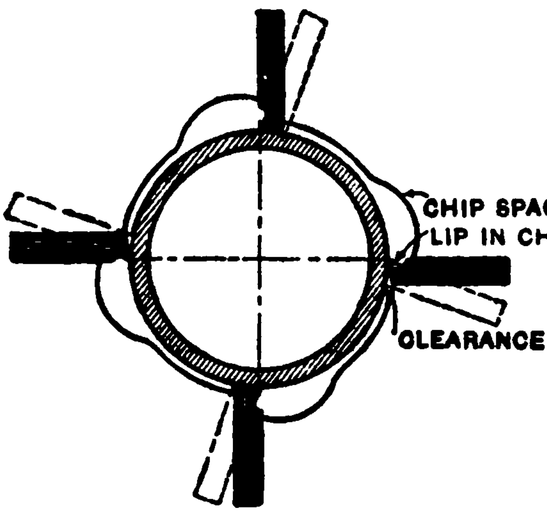


Fig. 3

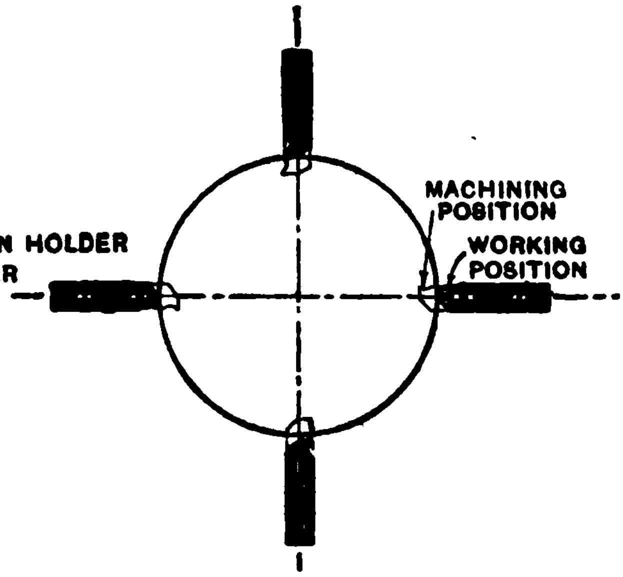


Fig. 4

indicated in Fig. 3, which shows the chip space in front of the chaser, the back of which should be well supported. This is a very important point and one which is often overlooked. A lack of chip space will cause the chips to clog and tear the threads.

Lead. Lead is the angle which is machined or ground on the front of each chaser to enable the die to start on the pipe, and also to distribute the work of cutting over a number of threads. The lead may be machined on, or, as is more frequent, it may be ground on after the chasers are tempered. To secure a good thread, the lead should cover the first three threads. As the heaviest cutting is done by the lead, it should have a slightly greater clearance angle than the rest of the threads on the chaser. When regrinding a chaser that has become dull on the lead, care should be taken to give each chaser the same length of lead, as otherwise the work will be unevenly distributed between the chasers.

Number of Chasers. To get good results in threading at one cut, experience shows that a die should have a suitable number of chasers, the number being determined by the size of the die. Our experience shows that dies up to 1¼ inches should have four (4) chasers.

1¼ inches to 4 inches	should	have	approximately	six chasers.
4 inches to 7 inches	"	"	"	eight chasers.
7 inches to 10 inches	"	"	"	ten chasers.
10 inches to 12 inches	"	"	"	twelve chasers.
12 inches to 14 inches	"	"	"	fourteen chasers.
14 inches to 18 inches	"	"	"	sixteen chasers.
18 inches to 20 inches	"	"	"	eighteen chasers.

Lubrication. Good lard or crude cottonseed oil should be used in liberal quantities. The best die made will not produce good results with poor oil.

Corrosion. The use of steel for welded pipe was made possible, in the first place, through the manufacture by the National Tube Company of a special grade of low-carbon steel, equal in welding quality to the wrought iron which had formerly been exclusively used for this purpose. Steel pipe has in later years superseded wrought-iron pipe by proving its superiority in strength, ductility, and finally, as made under modern processes, by its superior durability. As manufacturers of both wrought-iron and steel pipe for many years, we have had a special interest in this question of durability, about which there has been so much debate, and with our dual interest have had exceptional opportunities to make comparison of these materials under all manner of service. Moreover, we have always shipped a wrought-iron coupling on steel pipe, so that in case there was any outside corrosion, a comparison of the two materials could be readily made under the same conditions. As a result of an extended study of this question in the laboratory and in the field, and with the experience of many large consumers of pipe, who have made careful observations from cases where both iron and steel pipe were used under the same conditions, there was no further room for doubt as to the advantage of steel pipe, made under our methods of manufacture, in respect to its resistance to corrosion, particularly as to pitting; hence we abandoned the manufacture of charcoal and puddled iron for welded tubes and pipe after January, 1909.

For the information of those wishing to follow up the discussion of this subject, and obtain data regarding the tests and experiments which have been made on the relative corrosion of iron and steel, we give a list of publications below to which reference may be made: *

Proceedings of Engineers' Society of Western Pennsylvania, 1907.

T. N. Thomson, two reports, 1908–10, American Society of Heating and Ventilating Engineers.

American Society for Testing Materials, 1906, 1908 (Howe).

"Corrosion of Iron," A. Sang (McGraw-Hill Publishing Company). (Extensive bibliographs.)

"Corrosion and Preservation of Iron and Steel," A. S. Cushman and Hy. A. Gardner (McGraw-Hill Publishing Company).

"Metallurgy of Iron and Steel," Bradley Stoughton.

"Electrolytic Theory of the Corrosion of Iron and Its Applications," Wm. H. Walker (Journal Iron and Steel Institute, 1909).

"Function of Oxygen in the Corrosion of Metals," Wm. H. Walker (Transactions American Electrochemical Society, Vol. 14, p. 175).

"Corrosion of Iron and Steel," by J. N. Friend, 1911 (Longmans, Green and Company).

"Corrosion of Boiler Tubes," Jour. Am. Soc. Nav. Engrs., May, 1904.

National Tube Co. bulletins are published from time to time giving results of experience on this subject.

Cause of Corrosion. There is hardly space here to go very deeply into the question of corrosion in all its phases, about which there is still some

* An additional list of references will be found in appendix. (See index for page number.)

difference of opinion, but a few underlying facts which have recently been well established by experiments may be useful to those interested in protecting the metal.

It has been noticed by many who have worked on the problem of corrosion, that differences of electrolytic potential between two adjacent places on the surface of the metal causes local pitting. This difference may be due to lack of homogeneity in the metal, but more often is caused by foreign matter, electro-negative to iron, attached to the surface; such as mill scale, carbon, or rust itself. Without going into a discussion as to the fundamental causes, it has been clearly established that corrosion consists of two main reactions, viz.: the solution of a small portion of the iron in water, and the subsequent oxidation of the ferrous iron in solution to ferric hydroxide, which is then precipitated out as "rust." The amount of the corrosion is still further increased by the combination of free oxygen with the hydrogen, which was deposited on the surface of the metal when iron went into solution. This cycle of reactions is repeated, and the rust continues to accumulate so long as both water and air are present. Other agencies may accelerate the process of corrosion, but in the absence of either one of these elements no corrosion can take place. Steel will remain clean and bright for an indefinite time in dry air, and also in water that is free from air. Hence the necessity to see to it that, as far as possible, oxygen and other corrosive gases are removed from water, and that iron and steel exposed to moist air are protected by impervious and durable coatings.

We invite correspondence on this subject with our research department.

Mill Inspection and Tests. Every piece of pipe made in National Tube Company's mills is inspected for surface defects, and must stand an internal hydrostatic pressure test, without leaking, before shipment. Machines for applying this test are installed at convenient places throughout the mill. The amount of pressure applied depends on the use to which the pipe or tube is to be put, but in no case is it deemed advisable to test the finished pipe to more than one-half the elastic limit of the material, this being, however, as a rule, considerably above the actual working pressure. All boiler tubes and lap-weld pipe for certain purposes are subject to a flattening-test made on the crop ends cut from each piece of pipe. This is done to insure strong welds and sound material.

(For list of test pressures see pp. 68–76.)

Besides the regular internal pressure tests described above, lap-welded boiler tubes for locomotive service are given individual inspection and tests at the mill as follows:

1. Inspection of external and internal surface (the latter by the aid of reflected light).

2. The ends on being cut off are placed in a flanging press, designed by us especially for this purpose. The rough end is first pressed flat by a horizontal hydraulic press, then a die attached to a vertical plunger comes down and turns over a flange on the cut end of the sample, this combines a flattening, crushing-down, and flange test in one. As this test is made on each end of every locomotive boiler tube, the customer

has the utmost assurance that the material is of uniformly satisfactory quality. Tubes which fail to stand this test, on account of imperfect welding, are given another run through the furnace and rewelded, and are again subjected to the same test on the ends. Other physical tests are described in Standard Specifications for Locomotive Boiler Tubes, given on pages 99 to 102.

3. Our research department is continually testing and experimenting with the material for locomotive boiler tubes; this being the most severe service to which tubes are put, it is naturally the branch of the business to which we give most attention. To this end, tests of the safe ending quality are made on each lot; roller expander tests in the flue sheet, to determine the power of the material to withstand repeated working in the flue sheet without developing brittleness, are also made from time to time. Improvements in this line are reflected in the product designed for other purposes, where the demands of service are not so rigorous.

SHELBY SEAMLESS STEEL TUBES

Methods of Manufacture. The process employed in the manufacture of Shelby Seamless Tubes in our mill may be classified as follows:

A. Tubes made from solid round billets.....	(*a*) Hot finish. (*b*) Cold finish.
B. Tubes made from steel plates	(*a*) Hot finish. (*b*) Cold finish.

Class A includes by far the larger percentage of seamless tubes.

The preliminary operations are the same for hot and cold-finished tubes made from solid round billets. The steel, of a special quality, made by the basic open-hearth process, is rolled into rounds approximating in diameter that of the finished tube; these are cut to suitable length to contain sufficient steel for a required length tube, then heated to a soft plastic state and pierced. Before heating these billets a hole is drilled in the center of one end, so that the piercing point may be started accurately in the center of the billet, thereby minimizing, so far as possible, the variations of thickness in the wall. There results from this operation a rather rough, thick-walled seamless tube, retaining on its surface evidence of the manipulation required to work the hot billet into this shape. The roughly pierced tube is now transferred, without loss of time and without reheating, to a rolling mill, where it is passed between rolls having semicircular grooves between which various sizes of mandrels are placed, and are supported in this position on the ends of stiff bars. By repeatedly passing the rough tube through these rolls and over mandrels, the steel is gradually elongated and the walls proportionately reduced in gage.

Hot-finished Tubes are taken direct from the rolling mill while still retaining sufficient heat, and passed through a reeling machine of special design, which further slightly reduces the gage. The tube is straightened and given a burnished finish by this last operation.

Cold-finished Tubes. Where cold finish is required, the ends of the tubes after they leave the rolling mill are reduced, so that they may be firmly caught by the heavy tongs of the drawbench. They are first immersed in hot dilute acid to remove all scale outside and inside, so that a smooth, even surface may result from the cold drawing which follows. A mandrel is held in position by a long bar which lies inside the tube, and holds the mandrel just even with the die while the tube is being drawn. All tubes, except those having an inside diameter smaller than six-tenths of the outside diameter or smaller than ½ inch, are drawn over mandrels varying in diameter until the required diameter and thickness are obtained. The drawing operation hardens the steel, so that it is usually necessary to anneal the tube after each pass to restore its ductility, after which it is necessary to again put it through the acid pickling bath to remove the oxide-of-iron scale from the surface.

After the last drawing operation the hammered points are cut off, and the tube is ready for testing and final inspection.

Tubes Made from Steel Plates. As in the case of tubes made from round billets, these may be hot or cold finished, according to requirements. Hot-finished tubes are not as smooth as those cold drawn, hence, when it is necessary to produce a tube with smooth walls, it is given two or three cold passes, each operation being preceded by annealing and pickling.

The "cupping" process is used in making seamless tubes over 5½ inches outside diameter. Plates of the best-quality basic open-hearth steel of the required thickness are trimmed into circular shape and heated to a bright redness, then pressed roughly into the shape of a cup. This is repeated three or four times, reheating between each operation, and using smaller dies and punches as the process proceeds, until the cup has the shape of a cylinder closed at one end.

The piece is then taken to the drawbench, where it is further elongated and reduced in gage by forcing through dies of successively decreasing diameter.

Where a number of drawings are required, the piece is reheated before each draw. Finally the closed end, or head, is cut off and the tube cut to length.

Carbonic Acid Cylinders. These are made from specially selected steel plates (see cylinder specifications). The preliminary operations in the making of these cylinders are as above described, except that the head is not cut off, and the other or open end is swaged down to receive a head.

Materials. Three principal classes of material are used in the manufacture of seamless steel tubes, namely:

.17%-carbon open-hearth steel,
.35%-carbon " " "
3½%-nickel " " "

all of which are of special quality as before stated. In addition to these standard materials, tubes for special purposes are made from sp-

materials, such as chrome-vanadium steels, higher-carbon steels, etc. The physical qualities of all these materials vary with the heat treatment, especially after the cold-drawing operation, which hardens the tube.

The .17%-carbon steel tubes are suitable for boiler tubes and other purposes requiring great ductility; the .35%-carbon steel tubes are suitable for purposes in which higher elastic limits and ultimate strengths are required; and the 3½% nickel-steel tubes are suitable for purposes requiring ductility combined with high elastic limits and ultimate strengths.

Hot-finished tubes are not given any further heat treatment after leaving the hot mills. Cold-drawn tubes, however, are given regular heat treatments, which consist of either a soft anneal or a hard (finish) anneal, while for special purposes the heat treatment is varied to give properties suited to the purpose for which the tubes are to be used.

The average chemical and physical qualities of the three main classes of materials, when same are given the regular heat treatments after the final cold drawing, are shown in the following table.

Physical Properties of Shelby Seamless Steel Tubes

.17 *Per Cent Carbon Steel.*

Chemical Analysis:

Carbon	.14 to .19 per cent.
Manganese	.40 to .60 per cent.
Sulphur	.015 to .040 per cent.
Phosphorus	.010 to .035 per cent

Temper *S*. Physical Properties: (Unannealed)

Elastic limit	60 000 to 70 000 pounds per square inch.
Ultimate strength	65 000 to 80 000 pounds per square inch.
Elongation in 2 inches	12 to 18 per cent.
Elongation in 8 inches	3 to 7 per cent.
Reduction of area	20 to 30 per cent.

* Foot-pounds Energy Absorbed under Impact, 6.97.

(Material of this temper is of the maximum strength, with but slight ductility. The surface is bright and free from scale. Material of this temper is usually furnished for hose poles, cream separator bowls, etc.)

* The *impact test* is made on a machine of special design, constructed as follows: A pendulum with a light rigid frame system and a heavy lower part is hung on roller bearings; these are supported in a frame of sheet iron, attached to a heavy cast iron base. The pendulum is always dropped from a fixed height; in swinging, it moves before it a pointer which records the maximum height to which the pendulum swung. In making a test, the specimen to be tested is clamped firmly in the base of the machine; it is placed so that it will be struck by the pendulum at the lowest point in the swing. The test piece is 5/16 inch × 3/16 inch × 2¼ inches long, with a 60° notch cut 1/16 inch deep, 1⅝ inches from the end of the piece. When the test piece is firmly clamped in the base, the pendulum is suddenly released and, when striking the test piece, it is checked a certain amount depending on the toughness of the test piece. The height of the swing after hitting the test piece is recorded by the pointer. Knowing the weight of the pendulum, the height of the free swing and the height of the swing after striking the test piece, it is possible to calculate the foot-pounds energy absorbed by the test piece.

.17 *Per Cent Carbon Steel* (Continued).

Finish Anneal

Temper *T*. Physical Properties:
- Elastic limit............ 50 000 to 65 000 pounds per square inch.
- Ultimate strength....... 60 000 to 75 000 pounds per square inch.
- Elongation in 2 inches... 18 to 25 per cent.
- Elongation in 8 inches... 10 to 16 per cent.
- Reduction of area....... 35 to 45 per cent.
- Foot-pounds Energy Absorbed under Impact, 7.07.

(This temper is furnished for general mechanical purposes. It is slightly softer and considerably more ductile than Temper *S*. The surface is not bright, but free from scale.)

Temper *U*. Physical Properties: (Special Anneal)
- Elastic limit............ 40 000 to 54 000 pounds per square inch.
- Ultimate strength....... 53 000 to 65 000 pounds per square inch.
- Elongation in 2 inches... 35 to 45 per cent.
- Elongation in 8 inches... 15 to 20 per cent.
- Reduction of area....... 40 to 50 per cent.
- Foot-pounds Energy Absorbed under Impact, 8.70.

(Material of this temper will stand a moderate amount of cold forming, such as is necessary in the manufacture of bedsteads, etc. The surface is very slightly scaled.)

Temper *V*. Physical Properties: (Medium Anneal)
- Elastic limit............ 35 000 to 48 000 pounds per square inch.
- Ultimate strength....... 52 000 to 65 000 pounds per square inch.
- Elongation in 2 inches... 50 to 60 per cent.
- Elongation in 8 inches... 22 to 28 per cent.
- Reduction of area....... 50 to 60 per cent.
- Foot-pounds Energy Absorbed under Impact, 9.67.

(Material of this temper has lost all traces of the effect of cold drawing, and is in excellent shape for machining. However, the tools must have about 30 degrees top rake as the material comes away in long tough chips.)

Soft Anneal

Temper *W*. Physical Properties:
- Elastic limit............ 27 000 to 35 000 pounds per square inch.
- Ultimate strength....... 47 000 to 55 000 pounds per square inch.
- Elongation in 2 inches... 55 to 65 per cent.
- Elongation in 8 inches... 28 to 33 per cent.
- Reduction of area....... 52 to 62 per cent.
- Foot-pounds Energy Absorbed under Impact, 9.73.

(This temper is suitable for boiler tubes for all purposes. The material is soft and ductile and will stand considerable cold forming. The surface is slightly scaled.)

Temper *X*. Physical Properties: (Special Anneal)
- Elastic limit............ 30 000 to 35 000 pounds per square inch.
- Ultimate strength....... 50 000 to 56 000 pounds per square inch.
- Elongation in 2 inches... 55 to 65 per cent.
- Elongation in 8 inches... 28 to 33 per cent.
- Reduction of area....... 55 to 65 per cent.
- Foot-pounds Energy Absorbed under Impact, 9.42.

(This temper is suitable for all purposes requiring high ductility and resistance to shock, combined with highest tensile strength consistent with its ductility. Stay bolts are always furnished of this temper. The surface is considerably scaled.)

	Chemical analysis				Physical pulling tests			
	Carbon	Manganese	Sulphur	Phosphorus	Elastic limit	Tensile strength	Elongation in 8 ins.	Reduction in area
	%	%	%	%	Pounds	Pounds	%	%
Bessemer pipe steel..	.07	.30	.045	.100	36 000	58 000	22	55
Open-hearth pipe steel	.09	.40	.035	.025	33 000	53 000	25	60

In ductility this steel excels any material heretofore used in the manufacture of pipe. For bending into coils, or the various shapes required in electric conduit work, steel pipe is especially adapted. In this work it has given most satisfactory results; similarly, for boiler tubes or other purposes, where the metal has to stand cold flanging or other severe manipulation.

Welding and Annealing. Good welding quality is of prime importance in pipe steel, and is sought after and maintained by a system of careful inspection. This not only is an assurance that the seam will be strong and reliable, but is a quality highly desired in the shop where tubes or pipes have to be welded to each other, or to other material.

The welding heat naturally produces a larger grain in the metal. This does not necessarily mean loss of ductility, but, where a large margin of safety against failure by shock is desired, the grain may be refined by annealing. The method giving best results, is to heat the steel to a bright orange color in shop light (1750° F.) for a few minutes, allowing the piece to cool in the air — very slow cooling is not necessary. So treated, the fracture of the metal should show a fine silky texture without any trace of crystallization.

Threading. To insure a good threaded joint between a pipe and a fitting, it is necessary to have a clean, smoothly cut thread. To cut this kind of a thread, it is necessary to have a good die, which consists of a frame or holder and a set of chasers made with proper consideration for the following points: — lip, clearance, chip space, lead, and number of chasers.

Lip, which is also known as *hook* or *rake,* is the inclination of the cutting edge of the chaser to the surface of the pipe, as shown in Fig. 3. This lip may be secured by milling the cutting face of the chaser, as shown by the full lines, or by inclining the chaser, as shown by the dotted lines. This lip angle should be from 15° to 25°, depending upon the style and condition of the chasers and chaser holders.

Clearance. Clearance is the angle between the thread of the chasers and the threads of the pipe. This clearance may be secured in various ways, depending upon the position in which the chasers are held in the frame. The position of the cutting edge of the chaser in relation to the center line of the pipe while working, determines whether the chasers

shall be set "in" or "out" while the teeth are being machined, as shown in Figs. 3 and 4.

Chip Space. This is the space required in the holder in front of the chaser to allow room for the accumulation of chips, and also to provide means for lubricating the chasers. This space should be secured as

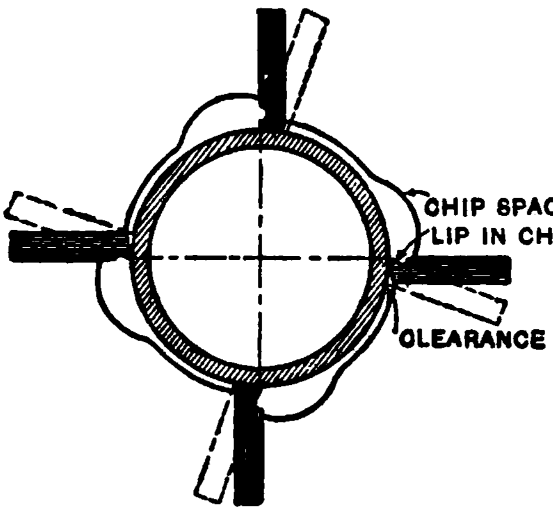


Fig. 3

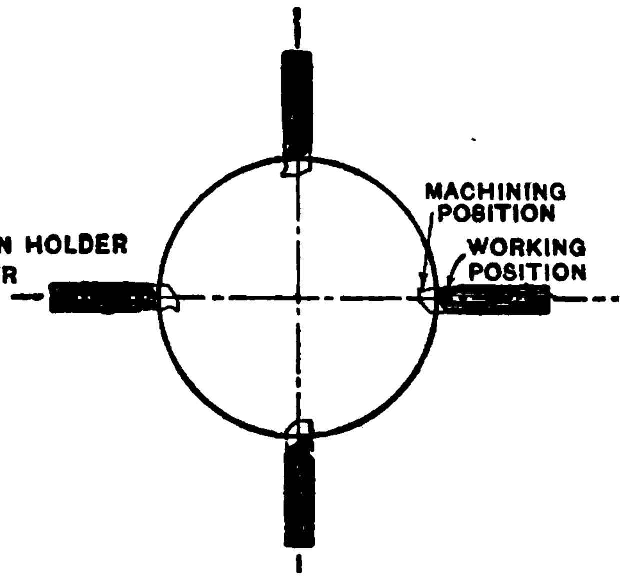


Fig. 4

indicated in Fig. 3, which shows the chip space in front of the chaser, the back of which should be well supported. This is a very important point and one which is often overlooked. A lack of chip space will cause the chips to clog and tear the threads.

Lead. Lead is the angle which is machined or ground on the front of each chaser to enable the die to start on the pipe, and also to distribute the work of cutting over a number of threads. The lead may be machined on, or, as is more frequent, it may be ground on after the chasers are tempered. To secure a good thread, the lead should cover the first three threads. As the heaviest cutting is done by the lead, it should have a slightly greater clearance angle than the rest of the threads on the chaser. When regrinding a chaser that has become dull on the lead, care should be taken to give each chaser the same length of lead, as otherwise the work will be unevenly distributed between the chasers.

Number of Chasers. To get good results in threading at one cut, experience shows that a die should have a suitable number of chasers, the number being determined by the size of the die. Our experience shows that dies up to 1¼ inches should have four (4) chasers.

1¼ inches	to 4 inches	should have approximately	six chasers.
4 inches	to 7 inches	" " "	eight chasers.
7 inches	to 10 inches	" " "	ten chasers.
10 inches	to 12 inches	" " "	twelve chasers.
12 inches	to 14 inches	" " "	fourteen chasers.
14 inches	to 18 inches	" " "	sixteen chasers.
18 inches	to 20 inches	" " "	eighteen chasers.

Lubrication. Good lard or crude cottonseed oil should be used in liberal quantities. The best die made will not produce good results with poor oil.

Corrosion. The use of steel for welded pipe was made possible, in the first place, through the manufacture by the National Tube Company of a special grade of low-carbon steel, equal in welding quality to the wrought iron which had formerly been exclusively used for this purpose. Steel pipe has in later years superseded wrought-iron pipe by proving its superiority in strength, ductility, and finally, as made under modern processes, by its superior durability. As manufacturers of both wrought-iron and steel pipe for many years, we have had a special interest in this question of durability, about which there has been so much debate, and with our dual interest have had exceptional opportunities to make comparison of these materials under all manner of service. Moreover, we have always shipped a wrought-iron coupling on steel pipe, so that in case there was any outside corrosion, a comparison of the two materials could be readily made under the same conditions. As a result of an extended study of this question in the laboratory and in the field, and with the experience of many large consumers of pipe, who have made careful observations from cases where both iron and steel pipe were used under the same conditions, there was no further room for doubt as to the advantage of steel pipe, made under our methods of manufacture, in respect to its resistance to corrosion, particularly as to pitting; hence we abandoned the manufacture of charcoal and puddled iron for welded tubes and pipe after January, 1909.

For the information of those wishing to follow up the discussion of this subject, and obtain data regarding the tests and experiments which have been made on the relative corrosion of iron and steel, we give a list of publications below to which reference may be made: *

Proceedings of Engineers' Society of Western Pennsylvania, 1907.

T. N. Thomson, two reports, 1908–10, American Society of Heating and Ventilating Engineers.

American Society for Testing Materials, 1906, 1908 (Howe).

"Corrosion of Iron," A. Sang (McGraw-Hill Publishing Company). (Extensive bibliographs.)

"Corrosion and Preservation of Iron and Steel," A. S. Cushman and Hy. A. Gardner (McGraw-Hill Publishing Company).

"Metallurgy of Iron and Steel," Bradley Stoughton.

"Electrolytic Theory of the Corrosion of Iron and Its Applications," Wm. H. Walker (Journal Iron and Steel Institute, 1909).

"Function of Oxygen in the Corrosion of Metals," Wm. H. Walker (Transactions American Electrochemical Society, Vol. 14, p. 175).

"Corrosion of Iron and Steel," by J. N. Friend, 1911 (Longmans, Green and Company).

"Corrosion of Boiler Tubes," Jour. Am. Soc. Nav. Engrs., May, 1904.

National Tube Co. bulletins are published from time to time giving results of experience on this subject.

Cause of Corrosion. There is hardly space here to go very deeply into the question of corrosion in all its phases, about which there is still some

* An additional list of references will be found in appendix. (See index for page number.)

difference of opinion, but a few underlying facts which have recently been well established by experiments may be useful to those interested in protecting the metal.

It has been noticed by many who have worked on the problem of corrosion, that differences of electrolytic potential between two adjacent places on the surface of the metal causes local pitting. This difference may be due to lack of homogeneity in the metal, but more often is caused by foreign matter, electro-negative to iron, attached to the surface; such as mill scale, carbon, or rust itself. Without going into a discussion as to the fundamental causes, it has been clearly established that corrosion consists of two main reactions, viz.: the solution of a small portion of the iron in water, and the subsequent oxidation of the ferrous iron in solution to ferric hydroxide, which is then precipitated out as "rust." The amount of the corrosion is still further increased by the combination of free oxygen with the hydrogen, which was deposited on the surface of the metal when iron went into solution. This cycle of reactions is repeated, and the rust continues to accumulate so long as both water and air are present. Other agencies may accelerate the process of corrosion, but in the absence of either one of these elements no corrosion can take place. Steel will remain clean and bright for an indefinite time in dry air, and also in water that is free from air. Hence the necessity to see to it that, as far as possible, oxygen and other corrosive gases are removed from water, and that iron and steel exposed to moist air are protected by impervious and durable coatings.

We invite correspondence on this subject with our research department.

Mill Inspection and Tests. Every piece of pipe made in National Tube Company's mills is inspected for surface defects, and must stand an internal hydrostatic pressure test, without leaking, before shipment. Machines for applying this test are installed at convenient places throughout the mill. The amount of pressure applied depends on the use to which the pipe or tube is to be put, but in no case is it deemed advisable to test the finished pipe to more than one-half the elastic limit of the material, this being, however, as a rule, considerably above the actual working pressure. All boiler tubes and lap-weld pipe for certain purposes are subject to a flattening-test made on the crop ends cut from each piece of pipe. This is done to insure strong welds and sound material.

(For list of test pressures see pp. 68–76.)

Besides the regular internal pressure tests described above, lap-welded boiler tubes for locomotive service are given individual inspection and tests at the mill as follows:

1. Inspection of external and internal surface (the latter by the aid of reflected light).

2. The ends on being cut off are placed in a flanging press, designed by us especially for this purpose. The rough end is first pressed flat by a horizontal hydraulic press, then a die attached to a vertical plunger comes down and turns over a flange on the cut end of the sample, this combines a flattening, crushing-down, and flange test in one. As this test is made on each end of every locomotive boiler tube, the customer

has the utmost assurance that the material is of uniformly satisfactory quality. Tubes which fail to stand this test, on account of imperfect welding, are given another run through the furnace and rewelded, and are again subjected to the same test on the ends. Other physical tests are described in Standard Specifications for Locomotive Boiler Tubes, given on pages 99 to 102.

3. Our research department is continually testing and experimenting with the material for locomotive boiler tubes; this being the most severe service to which tubes are put, it is naturally the branch of the business to which we give most attention. To this end, tests of the safe ending quality are made on each lot; roller expander tests in the flue sheet, to determine the power of the material to withstand repeated working in the flue sheet without developing brittleness, are also made from time to time. Improvements in this line are reflected in the product designed for other purposes, where the demands of service are not so rigorous.

SHELBY SEAMLESS STEEL TUBES

Methods of Manufacture. The process employed in the manufacture of Shelby Seamless Tubes in our mill may be classified as follows:

A. Tubes made from solid round billets..... { (*a*) Hot finish. (*b*) Cold finish.

B. Tubes made from steel plates .... { (*a*) Hot finish. (*b*) Cold finish.

Class A includes by far the larger percentage of seamless tubes.

The preliminary operations are the same for hot and cold-finished tubes made from solid round billets. The steel, of a special quality, made by the basic open-hearth process, is rolled into rounds approximating in diameter that of the finished tube; these are cut to suitable length to contain sufficient steel for a required length tube, then heated to a soft plastic state and pierced. Before heating these billets a hole is drilled in the center of one end, so that the piercing point may be started accurately in the center of the billet, thereby minimizing, so far as possible, the variations of thickness in the wall. There results from this operation a rather rough, thick-walled seamless tube, retaining on its surface evidence of the manipulation required to work the hot billet into this shape. The roughly pierced tube is now transferred, without loss of time and without reheating, to a rolling mill, where it is passed between rolls having semicircular grooves between which various sizes of mandrels are placed, and are supported in this position on the ends of stiff bars. By repeatedly passing the rough tube through these rolls and over mandrels, the steel is gradually elongated and the walls proportionately reduced in gage.

Hot-finished Tubes are taken direct from the rolling mill while still retaining sufficient heat, and passed through a reeling machine of special design, which further slightly reduces the gage. The tube is straightened and given a burnished finish by this last operation.

Cold-finished Tubes. Where cold finish is required, the ends of the tubes after they leave the rolling mill are reduced, so that they may be firmly caught by the heavy tongs of the drawbench. They are first immersed in hot dilute acid to remove all scale outside and inside, so that a smooth, even surface may result from the cold drawing which follows. A mandrel is held in position by a long bar which lies inside the tube, and holds the mandrel just even with the die while the tube is being drawn. All tubes, except those having an inside diameter smaller than six-tenths of the outside diameter or smaller than ½ inch, are drawn over mandrels varying in diameter until the required diameter and thickness are obtained. The drawing operation hardens the steel, so that it is usually necessary to anneal the tube after each pass to restore its ductility, after which it is necessary to again put it through the acid pickling bath to remove the oxide-of-iron scale from the surface.

After the last drawing operation the hammered points are cut off, and the tube is ready for testing and final inspection.

Tubes Made from Steel Plates. As in the case of tubes made from round billets, these may be hot or cold finished, according to requirements. Hot-finished tubes are not as smooth as those cold drawn, hence, when it is necessary to produce a tube with smooth walls, it is given two or three cold passes, each operation being preceded by annealing and pickling.

The "cupping" process is used in making seamless tubes over 5½ inches outside diameter. Plates of the best-quality basic open-hearth steel of the required thickness are trimmed into circular shape and heated to a bright redness, then pressed roughly into the shape of a cup. This is repeated three or four times, reheating between each operation, and using smaller dies and punches as the process proceeds, until the cup has the shape of a cylinder closed at one end.

The piece is then taken to the drawbench, where it is further elongated and reduced in gage by forcing through dies of successively decreasing diameter.

Where a number of drawings are required, the piece is reheated before each draw. Finally the closed end, or head, is cut off and the tube cut to length.

Carbonic Acid Cylinders. These are made from specially selected steel plates (see cylinder specifications). The preliminary operations in the making of these cylinders are as above described, except that the head is not cut off, and the other or open end is swaged down to receive a head.

Materials. Three principal classes of material are used in the manufacture of seamless steel tubes, namely:

.17%-carbon open-hearth steel,
.35%-carbon " " "
3½%-nickel " " "

all of which are of special quality as before stated. In addition to these standard materials, tubes for special purposes are made from special

materials, such as chrome-vanadium steels, higher-carbon steels, etc. The physical qualities of all these materials vary with the heat treatment, especially after the cold-drawing operation, which hardens the tube.

The .17%-carbon steel tubes are suitable for boiler tubes and other purposes requiring great ductility; the .35%-carbon steel tubes are suitable for purposes in which higher elastic limits and ultimate strengths are required; and the 3½% nickel-steel tubes are suitable for purposes requiring ductility combined with high elastic limits and ultimate strengths.

Hot-finished tubes are not given any further heat treatment after leaving the hot mills. Cold-drawn tubes, however, are given regular heat treatments, which consist of either a soft anneal or a hard (finish) anneal, while for special purposes the heat treatment is varied to give properties suited to the purpose for which the tubes are to be used.

The average chemical and physical qualities of the three main classes of materials, when same are given the regular heat treatments after the final cold drawing, are shown in the following table.

Physical Properties of Shelby Seamless Steel Tubes

.17 *Per Cent Carbon Steel.*

Chemical Analysis:

Carbon	.14 to .19 per cent.
Manganese	.40 to .60 per cent.
Sulphur	.015 to .040 per cent.
Phosphorus	.010 to .035 per cent

Temper *S*. Physical Properties: (Unannealed)

Elastic limit	60 000 to 70 000 pounds per square inch.
Ultimate strength	65 000 to 80 000 pounds per square inch.
Elongation in 2 inches	12 to 18 per cent.
Elongation in 8 inches	3 to 7 per cent.
Reduction of area	20 to 30 per cent.

*Foot-pounds Energy Absorbed under Impact, 6.97.

(Material of this temper is of the maximum strength, with but slight ductility. The surface is bright and free from scale. Material of this temper is usually furnished for hose poles, cream separator bowls, etc.)

* The *impact test* is made on a machine of special design, constructed as follows: A pendulum with a light rigid frame system and a heavy lower part is hung on roller bearings; these are supported in a frame of sheet iron, attached to a heavy cast iron base. The pendulum is always dropped from a fixed height; in swinging, it moves before it a pointer which records the maximum height to which the pendulum swung. In making a test, the specimen to be tested is clamped firmly in the base of the machine; it is placed so that it will be struck by the pendulum at the lowest point in the swing. The test piece is 5/16 inch × 3/16 inch × 2¼ inches long, with a 60° notch cut 1/16 inch deep, 1⅝ inches from the end of the piece. When the test piece is firmly clamped in the base, the pendulum is suddenly released and, when striking the test piece, it is checked a certain amount depending on the toughness of the test piece. The height of the swing after hitting the test piece is recorded by the pointer. Knowing the weight of the pendulum, the height of the free swing and the height of the swing after striking the test piece, it is possible to calculate the foot-pounds energy absorbed by the test piece.

.17 *Per Cent Carbon Steel* (Continued).

Finish Anneal

Temper *T*. Physical Properties:
Elastic limit............ 50 000 to 65 000 pounds per square inch.
Ultimate strength....... 60 000 to 75 000 pounds per square inch.
Elongation in 2 inches... 18 to 25 per cent.
Elongation in 8 inches... 10 to 16 per cent.
Reduction of area....... 35 to 45 per cent.
Foot-pounds Energy Absorbed under Impact, 7.07.

(This temper is furnished for general mechanical purposes. It is slightly softer and considerably more ductile than Temper *S*. The surface is not bright, but free from scale.)

Temper *U*. Physical Properties: (Special Anneal)
Elastic limit............ 40 000 to 54 000 pounds per square inch.
Ultimate strength....... 53 000 to 65 000 pounds per square inch.
Elongation in 2 inches... 35 to 45 per cent.
Elongation in 8 inches... 15 to 20 per cent.
Reduction of area....... 40 to 50 per cent.
Foot-pounds Energy Absorbed under Impact, 8.70.

(Material of this temper will stand a moderate amount of cold forming, such as is necessary in the manufacture of bedsteads, etc. The surface is very slightly scaled.)

Temper *V*. Physical Properties: (Medium Anneal)
Elastic limit............ 35 000 to 48 000 pounds per square inch.
Ultimate strength....... 52 000 to 65 000 pounds per square inch.
Elongation in 2 inches... 50 to 60 per cent.
Elongation in 8 inches... 22 to 28 per cent.
Reduction of area....... 50 to 60 per cent.
Foot-pounds Energy Absorbed under Impact, 9.67.

(Material of this temper has lost all traces of the effect of cold drawing, and is in excellent shape for machining. However, the tools must have about 30 degrees top rake as the material comes away in long tough chips.)

Soft Anneal

Temper *W*. Physical Properties:
Elastic limit............ 27 000 to 35 000 pounds per square inch.
Ultimate strength....... 47 000 to 55 000 pounds per square inch.
Elongation in 2 inches... 55 to 65 per cent.
Elongation in 8 inches... 28 to 33 per cent.
Reduction of area....... 52 to 62 per cent.
Foot-pounds Energy Absorbed under Impact, 9.73.

(This temper is suitable for boiler tubes for all purposes. The material is soft and ductile and will stand considerable cold forming. The surface is slightly scaled.)

Temper *X*. Physical Properties: (Special Anneal)
Elastic limit............ 30 000 to 35 000 pounds per square inch.
Ultimate strength....... 50 000 to 56 000 pounds per square inch.
Elongation in 2 inches... 55 to 65 per cent.
Elongation in 8 inches... 28 to 33 per cent.
Reduction of area....... 55 to 65 per cent.
Foot-pounds Energy Absorbed under Impact, 9.42.

(This temper is suitable for all purposes requiring high ductility and resistance to shock, combined with highest tensile strength consistent with its ductility. Stay bolts are always furnished of this temper. The surface is considerably scaled.)

.17 *Per Cent Carbon Steel* (Continued).

Temper *Y*. Physical Properties: (Retort Anneal)

Elastic limit............ 22 000 to 28 000 pounds per square inch.
Ultimate strength....... 45 000 to 52 000 pounds per square inch.
Elongation in 2 inches... 60 to 70 per cent.
Elongation in 8 inches... 30 to 40 per cent.
Reduction of area ...... 60 to 70 per cent.
Foot-pounds Energy Absorbed under Impact, 9.25.

(This temper is suitable for cold forming operations requiring maximum ductility. Sizes smaller than 1½ inches outside diameter can be furnished retort annealed if so specified. The surface of these tubes will be free from scale. Sizes larger than 1½ inches outside diameter will be annealed in the open furnace and the surface slightly scaled.)

Temper *Z*.:

(Material of this temper is hot rolled and the physical properties will vary with the wall thickness of the tubes. For wall thicknesses 3/16 inch and lighter, the physical properties will correspond very closely to Temper *U*. For heavier walls, the physical properties will correspond very closely to Temper *W*.)

.30 *to* .40 *Per Cent Carbon Steel.*

Chemical Analysis:

Carbon................ .30 to .40 per cent.
Manganese............. .40 to .60 per cent.
Phosphorus............ .010 to .035 per cent.
Sulphur................ .015 to .040 per cent.

Temper *S*. Physical Properties: (Unannealed)

Elastic limit............ 75 000 to 90 000 pounds per square inch.
Ultimate strength....... 85 000 to 100 000 pounds per square inch.
Elongation in 2 inches... 10 to 15 per cent.
Reduction of area....... 12 to 18 per cent.
Foot-pounds Energy Absorbed under Impact, 2.22.

(Material of this temper is hard and the surface bright. It has the maximum strength, but little ductility. It should not be used where it will be subjected to shock. Material which is to be heated above 500° C. during subsequent manufacture should be furnished of this temper.)

Finish Anneal

Temper *T*. Physical Properties:

Elastic limit............ 70 000 to 85 000 pounds per square inch.
Ultimate strength....... 80 000 to 95 000 pounds per square inch.
Elongation in 2 inches... 20 to 30 per cent.
Elongation in 8 inches... 12 to 18 per cent.
Reduction of area....... 25 to 32 per cent.
Foot-pounds Energy Absorbed under Impact, 3.55.

(This temper is usually furnished for automobile purposes requiring high-carbon steel.)

Medium Anneal

Temper *U*. Physical Properties:

Elastic limit............ 50 000 to 65 000 pounds per square inch.
Ultimate strength....... 65 000 to 80 000 pounds per square inch.
Elongation in 2 inches... 35 to 45 per cent.
Elongation in 8 inches... 20 to 30 per cent.
Reduction of area....... 35 to 42 per cent.
Foot-pounds Energy Absorbed under Impact, 5.55.

(This temper is suitable for purposes requiring high-tensile strength, good ductility and shock-resisting power.)

3½ Per Cent Nickel Steel.

Chemical Analysis:

Carbon	.20 to .30 per cent.	
Nickel	3.00 to 4.00 per cent.	
Manganese	.40 to .60 per cent.	
Phosphorus	.010 to .030 per cent.	
Sulphur	.015 to .040 per cent.	

Temper *S*. Physical Properties:

Elastic limit	85 000 to 100 000 pounds per square inch.
Ultimate strength	95 000 to 110 000 pounds per square inch.
Elongation in 2 inches	10 to 18 per cent.
Reduction of area	22 to 32 per cent.

Foot-pounds Energy Absorbed under Impact, 2.60.

(Material which is to be subsequently heat treated or heated above 500° C. in manufacturing processes should be furnished of this temper.)

Finish Anneal

Temper *W*. Physical Properties:

Elastic limit	75 000 to 90 000 pounds per square inch.
Ultimate strength	85 000 to 105 000 pounds per square inch.
Elongation in 2 inches	15 to 25 per cent.
Reduction of area	25 to 35 per cent.

Foot-pounds Energy Absorbed under Impact, 4.76.

(This temper is ideal for auto axles and all work requiring material of high-tensile strength and shock-resisting power.)

Medium Anneal

Temper *U*. Physical Properties:

Elastic limit	45 000 to 60 000 pounds per square inch.
Ultimate strength	70 000 to 85 000 pounds per square inch.
Elongation in 2 inches	40 to 50 per cent.
Elongation in 8 inches	20 to 28 per cent.
Reduction of area	45 to 50 per cent.

Foot-pounds Energy Absorbed under Impact, 9.18.

(Material of this temper is very ductile, has high shock-resisting power and is of relatively high tensile strength. It should find many uses where safety in construction is an important factor.)

Hot-finished boiler tubes have a slightly higher elastic limit and ultimate strength than the annealed cold-drawn, a fair average of their physical qualities being as follows:

Yield point	42 000 pounds per square inch.
Ultimate strength	62 000 pounds per square inch.
Elongation in 8 in.	22 per cent.
Reduction in area	48 per cent.

To suit the requirements of various customers, special treatments are given tubes, which produce a wide range in their physical qualities. Typical results obtained for two special treatments of .17%-carbon steel tubes are:

	(1)	(2)
Yield point	23 000 pounds per square inch	34 000 pounds per square inch.
Ultimate strength	48 000 pounds per square inch	55 000 pounds per square inch.
Elongation in 8 in.	35 per cent	28 per cent.
Reduction of area.	60 per cent	53 per cent.

All three of the main classes of material will case-harden, and this fact is taken advantage of by many users of case-hardened goods.

It will thus be seen that, with the variety of materials used for making tube and the various treatments afforded, almost any reasonable specification may be met, and the wants of a great variety of users may be satisfied.

Tests and Mill Inspection. For the purpose of obtaining tubes of highest quality, a system of inspections and tests, that will eliminate defective material, is regularly used. The inspections start with the bloom from which the round billets are made. Each bloom is laid on an inspection table and examined on all sides for defects. Blooms appearing defective are rejected. The next inspection takes place after tubes leave the hot mills. This inspection is for the purpose of eliminating surface defects. A final inspection for surface and gage is given the tubes after finishing, and just before packing or loading, to insure that material comes up to specifications.

Tests. Annealing operations are conducted in furnaces of special construction, equipped with pyrometers. Tests are made regularly to insure uniformity in the work.

All boiler tubes, both hot-finished and cold-drawn, are tested to 1000 pounds per square inch, hydrostatic pressure. Other tests applied to boiler tubes are given under the subject, "Specifications for Boiler Tubes."

It is advisable that the purpose for which the tubes are to be used be made known to the manufacturer, that the order may be executed intelligently, and that the limitations and difficulties of the process of manufacture be known in a general way by the purchaser, so that he may bear these things in mind in drawing up his specification. Our engineers will be pleased to comment on proposed specifications, and discuss details with those interested. A free discussion of such matters will, we believe, be of considerable benefit to all concerned.

MARKING

To readily identify "National" material, and as protection to manufacturer and consumer alike, the practice of the National Tube Company is to roll in raised letters of good size on each few feet of every length of welded pipe the name "NATIONAL" (except on the smaller butt-welded sizes, on which this is not mechanically feasible).

GENERAL NOTES

1. All weights are figured on the basis of one cubic inch of steel weighing .2833 pound and iron 2 per cent less.

2. All material will be cut to length when so ordered, with extreme variation not exceeding one-eighth of an inch over or under, unless otherwise arranged.

3. All pipe threaded to Briggs standard gages as made by Pratt and Whitney Company, Hartford, Conn.

4. In ordering designate weight or thickness desired, but not both.

5. All weights given in the tables are limited to three decimal places.

6. All weights given in the tables are for black pipe and couplings; galvanized pipe and couplings will be slightly heavier.

7. The outside diameter of all classes of pipe, casing, tubing, tubes, etc., heavier than standard is the same outside diameter as standard, the extra thickness always being on the inside.

8. Pipe and tubing are known and spoken of by their nominal inside diameters from ⅛ inch to 15 inches, inclusive. Casing is known by its inside diameter.

9. Above 15 inches inside diameter, pipe and tubing are always known and spoken of by their outside diameters, and when ordering, thickness desired must be specified.

10. Square and Rectangular Pipe are known by their outside dimensions.

11. All sizes of Converse, Matheson and Kimberley Joint Pipe and Bedstead Tubing are known by their outside diameters.

12. All Boiler Tubes are known by their outside diameters.

13. All dimensions of tubular goods are subject to change without notice.

14. For illustrations showing joints see pages 77 to 84.

15. For lists of test pressures see pages 68 to 76.

Standard Pipe — Black and Galvanized

All Weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per foot		Threads per inch	Couplings		
	External	Internal		Plain ends	Threads and couplings		Diameter	Length	Weight
1/8	.405	.269	.068	.244	.245	27	.562	7/8	.029
1/4	.540	.364	.088	.424	.425	18	.685	1	.043
3/8	.675	.493	.091	.567	.568	18	.848	1 1/8	.070
1/2	.840	.622	.109	.850	.852	14	1.024	1 3/8	.116
3/4	1.050	.824	.113	1.130	1.134	14	1.281	1 5/8	.209
1	1.315	1.049	.133	1.678	1.684	11 1/2	1.576	1 7/8	.343
1 1/4	1.660	1.380	.140	2.272	2.281	11 1/2	1.950	2 1/8	.535
1 1/2	1.900	1.610	.145	2.717	2.731	11 1/2	2.218	2 3/8	.743
2	2.375	2.067	.154	3.652	3.678	11 1/2	2.760	2 5/8	1.208
2 1/2	2.875	2.469	.203	5.793	5.819	8	3.276	2 7/8	1.720
3	3.500	3.068	.216	7.575	7.616	8	3.948	3 1/8	2.498
3 1/2	4.000	3.548	.226	9.109	9.202	8	4.591	3 5/8	4.241
4	4.500	4.026	.237	10.790	10.889	8	5.091	3 5/8	4.741
4 1/2	5.000	4.506	.247	12.538	12.642	8	5.591	3 5/8	5.241
5	5.563	5.047	.258	14.617	14.810	8	6.296	4 1/8	8.091
6	6.625	6.065	.280	18.974	19.185	8	7.358	4 1/8	9.554
7	7.625	7.023	.301	23.544	23.769	8	8.358	4 1/8	10.932
8	8.625	8.071	.277	24.696	25.000	8	9.358	4 5/8	13.905
8	8.625	7.981	.322	28.554	28.809	8	9.358	4 5/8	13.905
9	9.625	8.941	.342	33.907	34.188	8	10.358	5 1/8	17.236
10	10.750	10.192	.279	31.201	32.000	8	11.721	6 1/8	29.877
10	10.750	10.136	.307	34.240	35.000	8	11.721	6 1/8	29.877
10	10.750	10.020	.365	40.483	41.132	8	11.721	6 1/8	29.877
11	11.750	11.000	.375	45.557	46.247	8	12.721	6 1/8	32.550
12	12.750	12.090	.330	43.773	45.000	8	13.958	6 1/8	43.098
12	12.750	12.000	.375	49.562	50.706	8	13.958	6 1/8	43.098
13	14.000	13.250	.375	54.568	55.824	8	15.208	6 1/8	47.152
14	15.000	14.250	.375	58.573	60.375	8	16.446	6 1/8	59.493
15	16.000	15.250	.375	62.579	64.500	8	17.446	6 1/8	63.294

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with threads and couplings and in random lengths unless otherwise ordered.

Taper of threads is 3/4 inch diameter per foot length for all sizes.

The weight per foot of pipe with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet.

All weights given in pounds. All dimensions given in inches.

On sizes made in more than one weight, weight desired must be specified.

For general notes see page 21.

For test pressures see page 68. For illustration showing joint see page 77.

Line Pipe

All Weights and Dimensions are Nominal

Size	Diameters External	Diameters Internal	Thickness	Weight per foot Plain ends	Weight per foot Threads and couplings	Threads per inch	Couplings Diameter	Couplings Length	Couplings Weight
1/8	.405	.269	.068	.244	.246	27	.582	1 1/8	.043
1/4	.540	.364	.088	.424	.426	18	.724	1 3/8	.069
3/8	.675	.493	.091	.567	.571	18	.898	1 5/8	.126
1/2	.840	.622	.109	.850	.856	14	1.085	1 7/8	.205
3/4	1.050	.824	.113	1.130	1.138	14	1.316	2 1/8	.316
1	1.315	1.049	.133	1.678	1.688	11 1/2	1.575	2 3/8	.445
1 1/4	1.660	1.380	.140	2.272	2.300	11 1/2	2.054	2 7/8	.974
1 1/2	1.900	1.610	.145	2.717	2.748	11 1/2	2.294	2 7/8	1.103
2	2.375	2.067	.154	3.652	3.716	11 1/2	2.841	3 5/8	2.146
2 1/2	2.875	2.469	.203	5.793	5.881	8	3.389	4 1/8	3.387
3	3.500	3.068	.216	7.575	7.675	8	4.014	4 1/8	4.076
3 1/2	4.000	3.548	.226	9.109	9.261	8	4.628	4 1/8	5.510
4	4.500	4.026	.237	10.790	10.980	8	5.233	4 1/8	6.673
4 1/2	5.000	4.506	.247	12.538	12.742	8	5.733	4 1/8	7.379
5	5.563	5.047	.258	14.617	14.966	8	6.420	5 1/8	11.730
6	6.625	6.065	.280	18.974	19.367	8	7.482	5 1/8	13.869
7	7.625	7.023	.301	23.544	23.975	8	8.482	5 1/8	15.883
8	8.625	8.071	.277	24.696	25.414	8	9.596	6 1/8	24.130
8	8.625	7.981	.322	28.554	29.213	8	9.596	6 1/8	24.130
9	9.625	8.941	.342	33.907	34.612	8	10.596	6 1/8	26.838
10	10.750	10.192	.279	31.201	32.515	8	11.958	6 5/8	39.772
10	10.750	10.136	.307	34.240	35.504	8	11.958	6 5/8	39.772
10	10.750	10.020	.365	40.483	41.644	8	11.958	6 5/8	39.772
11	11.750	11.000	.375	45.557	46.805	8	12.958	6 5/8	43.326
12	12.750	12.090	.330	43.773	45.217	8	13.958	6 5/8	46.898
12	12.750	12.000	.375	49.562	50.916	8	13.958	6 5/8	46.898
13	14.000	13.250	.375	54.568	56.649	8	15.446	7 1/8	65.506
14	15.000	14.250	.375	58.573	60.802	8	16.446	7 1/8	70.031
15	16.000	15.250	.375	62.579	64.955	8	17.446	7 1/8	74.555

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with threads and couplings and in random lengths unless otherwise ordered.

Taper of threads is 3/4 inch diameter per foot length for all sizes.

The weight per foot of pipe with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet. All weights given in pounds. All dimensions given in inches.

On sizes made in more than one weight, weight desired must be specified.

For general notes see page 21.

For test pressures see page 68. For illustration showing joint see page 77.

Drive Pipe

All Weights and Dimensions are Nominal

Size	Diameters External	Diameters Internal	Thickness	Weight per foot Plain ends	Weight per foot Threads and couplings	Threads per inch	Couplings Diameter	Couplings Length	Couplings Weight
2	2.375	2.067	.154	3.652	3.730	11½	2.923	3⅝	2.380
2½	2.875	2.469	.203	5.793	5.906	8	3.486	4⅛	3.748
3	3.500	3.068	.216	7.575	7.705	8	4.111	4⅛	4.493
3½	4.000	3.548	.226	9.109	9.294	8	4.723	4⅛	5.973
4	4.500	4.026	.237	10.790	10.995	8	5.223	4⅛	6 740
4½	5.000	4.506	.247	12.538	12.758	8	5.723	4⅛	7.439
5	5.563	5.047	.258	14.617	14.989	8	6.410	5⅛	11.871
6	6.625	6.065	.280	18.974	19.408	8	7.473	5⅛	13.956
7	7.625	7.023	.301	23.544	24.021	8	8.474	5⅛	15.955
8	8.625	8.071	.277	24.696	25.495	8	9.588	6⅛	24.343
8	8.625	7.981	.322	28.554	29.303	8	9.588	6⅛	24.343
8	8.625	7.917	.354	31.270	32.334	8	9.882	6⅛	31.320
9	9.625	8.941	.342	33.907	34.711	8	10.588	6⅛	27.035
10	10.750	10.192	.279	31.201	32.631	8	11.950	6⅝	40.108
10	10.750	10.136	.307	34.240	35.628	8	11.950	6⅝	40.108
10	10.750	10.020	.365	40.483	41.785	8	11.950	6⅝	40.108
11	11.750	11.000	.375	45.557	46.953	8	12.950	6⅝	43.664
12	12.750	12.090	.330	43.773	45.358	8	13.950	6⅝	47.220
12	12.750	12.000	.375	49.562	51.067	8	13.950	6⅝	47.220
13	14.000	13.250	.375	54.568	56.849	8	15.438	7⅛	66.024
14	15.000	14.250	.375	58.573	61.005	8	16.438	7⅛	70.533
15	16.000	15.250	.375	62.579	65.161	8	17.438	7⅛	75.043
17 O.D.	17.000	16.214	.393	69.704	73.000	8	18.675	7⅛	91.746
18 O.D.	18.000	17.182	.409	76.840	81.000	8	19.913	7⅛	109.669
20 O.D.	20.000	19.182	.409	85.577	90.000	8	21.913	7⅛	121.298

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with threads and couplings and in random lengths unless otherwise ordered.

Taper of threads is ¾ inch from 2 inches to 5 inches, and 5/16 inch from 6 inches to 20 inches.

The weight per foot of pipe with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet.

All weights given in pounds. All dimensions given in inches.

On sizes made in more than one weight, weight desired must be specified.

For general notes see page 21.

For test pressures see page 69.

For illustration showing joint see page 77.

Extra Strong Pipe — Black and Galvanized
All Weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per foot plain ends
	External	Internal		
1/8	.405	.215	.095	.314
1/4	.540	.302	.119	.535
3/8	.675	.423	.126	.738
1/2	.840	.546	.147	1.087
3/4	1.050	.742	.154	1.473
1	1.315	.957	.179	2.171
1 1/4	1.660	1.278	.191	2.996
1 1/2	1.900	1.500	.200	3.631
2	2.375	1.939	.218	5.022
2 1/2	2.875	2.323	.276	7.661
3	3.500	2.900	.300	10.252
3 1/2	4.000	3.364	.318	12.505
4	4.500	3.826	.337	14.983
4 1/2	5.000	4.290	.355	17.611
5	5.563	4.813	.375	20.778
6	6.625	5.761	.432	28.573
7	7.625	6.625	.500	38.048
8	8.625	7.625	.500	43.388
9	9.625	8.625	.500	48.728
10	10.750	9.750	.500	54.735
11	11.750	10.750	.500	60.075
12	12.750	11.750	.500	65.415
13	14.000	13.000	.500	72.091
14	15.000	14.000	.500	77.431
15	16.000	15.000	.500	82.771

The permissible variation in weight is 5 per cent above and 5 per cent below.

Double Extra Strong Pipe — Black and Galvanized
All Weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per foot plain ends
	External	Internal		
1/2	.840	.252	.294	1.714
3/4	1.050	.434	.308	2.440
1	1.315	.599	.358	3.659
1 1/4	1.660	.896	.382	5.214
1 1/2	1.900	1.100	.400	6.408
2	2.375	1.503	.436	9.029
2 1/2	2.875	1.771	.552	13.695
3	3.500	2.300	.600	18.583
3 1/2	4.000	2.728	.636	22.850
4	4.500	3.152	.674	27.541
4 1/2	5.000	3.580	.710	32.530
5	5.563	4.063	.750	38.552
6	6.625	4.897	.864	53.160
7	7.625	5.875	.875	63.079
8	8.625	6.875	.875	72.424

The permissible variation in weight is 10 per cent above and 10 per cent below.
The following notes apply to both tables.
Furnished with plain ends and in random lengths unless otherwise ordered.
All weights given in pounds. All dimensions given in inches. For general notes see page 21. For test pressures see page 69.

Standard Boston Casing

All Weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per foot		Threads per inch	Couplings		
	External	Internal		Plainends	Threads and couplings		Diameter	Length	Weight
2	2.250	2.050	.100	2.296	2.340	14	2.714	2⅝	1.361
2¼	2.500	2.284	.108	2.759	2.820	14	2.964	2⅝	1.499
2½	2.750	2.524	.113	3.182	3.250	14	3.214	2⅞	1.804
2¾	3.000	2.768	.116	3.572	3.650	14	3.464	2⅞	1.957
3	3.250	3.010	.120	4.011	4.100	14	3.771	3⅛	2.612
3¼	3.500	3.250	.125	4.505	4.600	14	4.021	3⅛	2.799
3½	3.750	3.492	.129	4.988	5.100	14	4.271	3⅛	2.987
3¾	4.000	3.732	.134	5.532	5.650	14	4.521	3⅛	3.174
4	4.250	3.974	.138	6.060	6.200	14	4.771	3⅝	3.923
4¼	4.500	4.216	.142	6.609	6.750	14	5.021	3⅝	4.141
4¼	4.500	4.090	.205	9.403	9.500	14	5.021	3⅝	4.141
4½	4.750	4.460	.145	7.131	7.250	14	5.271	3⅝	4.360
4½	4.750	4.364	.193	9.393	9.500	14	5.271	3⅝	4.360
4¾	5.000	4.696	.152	7.870	8.000	14	5.521	3⅝	4.578
5	5.250	4.944	.153	8.328	8.500	14	5.828	4⅛	5.929
5	5.250	4.886	.182	9.851	10.000	14	5.828	4⅛	5.929
5	5.250	4.886	.182	9.851	10.000	11½	5.800	4⅛	5.742
5	5.250	4.768	.241	12.892	13.000	11½	5.800	4⅛	5.742
5	5.250	4.648	.301	15.909	16.000	11½	5.800	4⅛	5.742
5 3/16	5.500	5.192	.154	8.792	9.000	14	6.078	4⅛	6.200
5⅝	6.000	5.672	.164	10.222	10.500	14	6.664	4⅛	7.729
5⅝	6.000	5.620	.190	11.789	12.000	11½	6.636	4⅛	7.516
5⅝	6.000	5.552	.224	13.818	14.000	11½	6.636	4⅛	7.516
5⅝	6.000	5.450	.275	16.814	17.000	11½	6.636	4⅛	7.516
6¼	6.625	6.287	.169	11.652	12.000	14	7.308	4⅝	9.825
6¼	6.625	6.255	.185	12.724	13.000	14	7.308	4⅝	9.825
6⅝	7.000	6.652	.174	12.685	13.000	14	7.692	4⅝	10.497
6⅝	7.000	6.538	.231	16.699	17.000	11½	7.664	4⅝	10.225
7¼	7.625	7.263	.181	14.390	14.750	14	8.317	4⅝	11.401
7⅝	8.000	7.628	.186	15.522	16.000	11½	8.788	5⅛	15.308
7⅝	8.000	7.528	.236	19.569	20.000	11½	8.788	5⅛	15.308
8¼	8.625	8.249	.188	16.940	17.500	11½	9.413	5⅛	16.461
8¼	8.625	8.191	.217	19.486	20.000	11½	9.413	5⅛	16.461
8¼	8.625	8.097	.264	23.574	24.000	11½	9.413	5⅛	16.461
8⅝	9.000	8.608	.196	18.429	19.000	11½	9.788	5⅛	17.153
9⅝	10.000	9.582	.209	21.855	22.750	11½	10.911	6⅛	26.136
10⅝	11.000	10.552	.224	25.780	26.750	11½	11.911	6⅛	28.536
11⅝	12.000	11.514	.243	30.512	31.500	11½	12.911	6⅛	31.051
12½	13.000	12.482	.259	35.243	36.500	11½	14.025	6⅛	37.499
13½	14.000	13.448	.276	40.454	42.000	11½	15.139	6⅛	44.495
14½	15.000	14.418	.291	45.714	47.500	11½	16.263	6⅛	52.401
15½	16.000	15.396	.302	50.632	52.500	11½	17.263	6⅛	55.779

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with threads and couplings and in random lengths unless otherwise rdered. Taper of threads is ⅝ inch diameter per foot length for all sizes.

Thickness of walls make it impracticable to cut threads of coarser pitch than hown on table. The weight per foot of casing with threads and couplings is ased on a length of 20 feet, including the coupling, but shipping lengths of small izes will usually average less than 20 feet. All weights given in pounds. All imensions given in inches.

On sizes made in more than one weight or thread, weight and number of threads esired must be specified. For general notes see page 21.

For test pressures see page 70. For illustration showing joint see page 78.

Inserted Joint Casing

All Weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per foot plain ends	Threads per inch	Joint	
	External	Internal				Length of Joint —"L"	Diameter of joint —"D"
2	2.250	2.050	.100	2.296	14	.967	2.340
2¼	2.500	2.284	.108	2.759	14	.992	2.606
2½	2.750	2.524	.113	3.182	14	1.017	2.866
2¾	3.000	2.768	.116	3.572	14	1.042	3.122
3	3.250	3.010	.120	4.011	14	1.067	3.380
3¼	3.500	3.250	.125	4.505	14	1.092	3.640
3½	3.750	3.492	.129	4.988	14	1.117	3.898
3¾	4.000	3.732	.134	5.532	14	1.142	4.158
4	4.250	3.974	.138	6.060	14	1.167	4.416
4¼	4.500	4.216	.142	6.609	14	1.192	4 674
4½	4.750	4.460	.145	7.131	14	1.217	4.930
4¾	5.000	4.696	.152	7.870	14	1.242	5.194
5	5.250	4.944	.153	8.328	14	1.267	5.446
5³⁄₁₆	5.500	5.192	.154	8.792	14	1.292	5.698
5⅝	6.000	5.672	.164	10.222	14	1.342	6.218
5⅝	6.000	5.620	.190	11.789	11½	1.373	6.246
6¼	6.625	6.287	.169	11.652	14	1.405	6.853
6⅝	7.000	6.652	.174	12.685	14	1.442	7.238
7¼	7.625	7.263	.181	14.390	14	1.505	7.877
7⅝	8.000	7.628	.186	15.522	11½	1.573	8.238
8¼	8.625	8.249	.188	16.940	11½	1.636	8.867
8⅝	9.000	8.608	.196	18.429	11½	1.673	9.258
9⅝	10.000	9.582	.209	21.855	11½	1.773	10.284
10⅝	11.000	10.552	.224	25.780	11½	1.873	11.314
11⅝	12.000	11.514	.243	30.512	11½	1.973	12.352
12½	13.000	12.482	.259	35.243	11½	2.073	13.384
13½	14.000	13.448	.276	40.454	11½	2.173	14.418
14½	15.000	14.418	.291	45.714	11½	2.273	15.448
15½	16.000	15.396	.302	50.632	11½	2.373	16.470

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished in random lengths unless otherwise ordered.

Regular taper of threads is ⅜ inch diameter per foot length for all sizes, but will furnish ¼ inch, ½ inch, or ⅝ inch taper if so ordered.

All weights given in pounds. All dimensions given in inches.

On sizes made in more than one weight or thread, weight and number of threads desired must be specified.

Thickness of walls make it impracticable to cut threads of coarser pitch than shown on table.

For general notes see page 21.

For test pressures see page 71.

For illustration showing joint see page 78.

Boston Casing — Pacific Couplings
All Weights and Dimensions are Nominal

Size	Diameters: External	Diameters: Internal	Thickness	Weight per foot: Plain ends	Weight per foot: Threads and couplings	Threads per inch	Couplings: Diameter	Couplings: Length	Couplings: Weight
3¾	4.000	3.732	.134	5.532	5.678	14	4.525	4⅛	4.367
4	4.250	3.974	.138	6.060	6.223	14	4.828	4⅛	4.844
4¼	4.500	4.216	.142	6.609	6.779	14	5.078	4⅛	5.115
4¼	4.500	4.090	.205	9.403	9.547	14	5.078	4⅛	5.115
4½	4.750	4.460	.145	7.131	7.309	14	5.328	4⅛	5.387
4½	4.750	4.364	.193	9.393	9.550	14	5.328	4⅛	5.387
4¾	5.000	4.696	.152	7.870	8.093	14	5.664	4⅛	6.456
5	5.250	4.944	.153	8.328	8.562	14	5.914	4⅛	6.764
5	5.250	4.886	.182	9.851	10.071	14	5.914	4⅛	6.764
5	5.250	4.886	.182	9.851	10.057	11½	5.886	4⅛	6.575
5	5.250	4.768	.241	12.892	13.085	14	5.914	4⅛	6.764
5	5.250	4.768	.241	12.892	13.072	11½	5.886	4⅛	6.575
5	5.250	4.648	.301	15.909	16.062	11½	5.886	4⅛	6.575
5⅝	6.000	5.672	.164	10.222	10.528	14	6.692	4⅝	9.052
5⅝	6.000	5.620	.190	11.789	12.063	11½	6.664	4⅝	8.814
5⅝	6.000	5.552	.224	13.818	14.069	11½	6.664	4⅝	8.814
5⅝	6.000	5.450	.275	16.814	17.033	11½	6.664	4⅝	8.814
6¼	6.625	6.287	.169	11.652	11.986	14	7.317	4⅝	9.955
6¼	6.625	6.255	.185	12.724	13.046	14	7.317	4⅝	9.955
6¼	6.625	6.255	.185	12.724	13.028	11½	7.289	4⅝	9.696
6⅝	7.000	6.652	.174	12.685	13.122	14	7.816	4⅝	12.274
6⅝	7.000	6.538	.231	16.699	17.076	11½	7.788	4⅝	12.000
7⅝	8.000	7.628	.186	15.522	16.038	11½	8.788	5⅛	15.308
7⅝	8.000	7.528	.236	19.569	20.037	11½	8.788	5⅛	15.308
8⅝	9.000	8.608	.196	18.429	19.123	11½	9.911	5⅛	19.667
9⅝	10.000	9.582	.209	21.855	22.802	11½	11.084	5⅛	25.624
9⅝	10.000	9.434	.283	29.369	30.250	11½	11.084	5⅛	25.624
10⅝	11.000	10.552	.224	25.780	26.978	11½	12.084	6⅛	33.764
11⅝	12.000	11.514	.243	30.512	31.872	11½	13.139	6⅛	38.477
12½	13.000	12.482	.259	35.243	36.685	11½	14.139	6⅛	41.568
13½	14.000	13.448	.276	40.454	41.975	11½	15.139	6⅛	44.659
14½	15.000	14.418	.291	45.714	48.018	11½	16.500	6⅛	61.800
15½	16.000	15.396	.302	50.632	53.068	11½	17.500	6⅛	65.758

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with threads and couplings and in random lengths unless otherwise ordered. Taper of threads is ¾ inch diameter per foot length for all sizes.

The weight per foot of casing with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet. All weights given in pounds. All dimensions given in inches. On sizes made in more than one weight or thread, weight and number of threads desired must be specified.

Thickness of walls make it impracticable to cut threads of coarser pitch than shown on table. For general notes see page 21.

For test pressures see page 70. For illustration showing joint see page 78.

California Diamond BX Casing

All Weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per foot		Threads per inch	Couplings		
	External	Internal		Plain ends	Threads and couplings		Diameter	Length	Weight
5⅝	6.000	5.352	.324	19.641	20.000	10	6.765	7⅛	15.748
6¼	6.625	6.049	.288	19.491	20.000	10	7.390	7⅝	18.559
6¼	6.625	5.921	.352	23.582	24.000	10	7.390	7⅝	18.559
6¼	6.625	5.855	.385	25.658	26.000	10	7.390	7⅝	18.559
6¼	6.625	5.791	.417	27.648	28.000	10	7.390	7⅝	18.559
6⅝	7.000	6.456	.272	19.544	20.000	10	7.698	7⅝	17.943
6⅝	7.000	6.276	.362	25.663	26.000	10	7.698	7⅝	17.943
6⅝	7.000	6.214	.393	27.731	28.000	10	7.698	7⅝	17.943
6⅝	7.000	6.154	.423	29.712	30.000	10	7.698	7⅝	17.943
7⅝	8.000	7.386	.307	25.223	26.000	10	8.888	8⅛	27.410
8¼	8.625	8.017	.304	27.016	28.000	10	9.627	8⅛	33.096
8¼	8.625	7.921	.352	31.101	32.000	10	9.627	8⅛	33.096
8¼	8.625	7.825	.400	35.137	36.000	10	9.627	8⅛	33.096
8¼	8.625	7.775	.425	37.220	38.000	10	9.627	8⅛	33.096
8¼	8.625	7.651	.487	42.327	43.000	10	9.627	8⅛	33.096
9⅝	10.000	9.384	.308	31.881	33.000	10	11.002	8⅛	38.162
10	10.750	10.054	.348	38.661	40.000	10	11.866	8⅛	45.365
10	10.750	9.960	.395	43.684	45.000	10	11.866	8⅛	45.365
10	10.750	9.902	.424	46.760	48.000	10	11.866	8⅛	45.365
10	10.750	9.784	.483	52.962	54.000	10	11.866	8⅛	45.365
11⅝	12.000	11.384	.308	38.460	40.000	10	13.116	8⅛	50.445
12½	13.000	12.438	.281	38.171	40.000	10	14.116	8⅛	54.508
12½	13.000	12.360	.320	43.335	45.000	10	14.116	8⅛	54.508
12½	13.000	12.282	.359	48.467	50.000	10	14.116	8⅛	54.508
13½	14.000	13.344	.328	47.894	50.000	10	15.151	9⅛	67.912
15½	16.000	15.198	.401	66.806	70.000	10	17.477	9⅛	98.140

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with threads and couplings and in random lengths unless otherwise ordered.

Taper of threads is ⅝ inch diameter per foot length for all sizes.

The weight per foot of casing with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet.

All weights given in pounds. All dimensions given in inches.

This casing not furnished in lighter weights, but can be made heavier than shown above.

When one size of casing is intended to telescope with another, it should always be specified when ordering.

On sizes made in more than one weight, weight desired must be specified.

For general notes see page 21. For test pressures see page 71.

For illustration showing joint see page 82.

Oil Well Tubing

All Weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per foot		Threads per inch	Couplings		
	External	Internal		Plain ends	Threads and couplings		Diameter	Length	Weight
1¼	1.660	1.380	.140	2.272	2.300	11½	2.054	2⅞	.974
1½	1.900	1.610	.145	2.717	2.748	11½	2.294	2⅞	1.103
2	2.375	2.041	.167	3.938	4.000	11½	2.841	3⅝	2.146
2	2.375	1.995	.190	4.433	4.500	11½	2.841	3⅝	2.146
2½	2.875	2.469	.203	5.793	5.897	11½	3.449	4⅛	3.636
2½	2.875	2.441	.217	6.160	6.250	11½	3.449	4⅛	3.636
3	3.500	3.068	.216	7.575	7.694	11½	4.074	4⅛	4.366
3	3.500	3.018	.241	8.388	8.500	11½	4.074	4⅛	4.366
3	3.500	2.922	.289	9.910	10.000	11½	4.074	4⅛	4.366
3½	4.000	3.548	.226	9.109	9.261	8	4.628	4⅛	5.510
4	4.500	4.026	.237	10.790	10.980	8	5.233	4⅛	6.673
4	4.500	3.990	.255	11.561	11.750	8	5.233	4⅛	6.673

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with threads and couplings and in random lengths unless otherwise ordered.

Taper of threads is ¾ inch diameter per foot length for all sizes.

The weight per foot of tubing with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet.

All weights given in pounds. All dimensions given in inches.

On sizes made in more than one weight, weight desired must be specified.

For general notes see page 21. For test pressures see page 69.

For illustration showing joint see page 81.

California Special External Upset Tubing

All Weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per foot		Threads per inch	Couplings		
	External	Internal		Plain ends	Threads and couplings		Diameter	Length	Weight
3	3.500	3.018	.241	8.388	8.627	10	4.504	5⅛	7.627
4	4.500	3.958	.271	12.240	12.500	10	5.349	6⅛	9.511

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with threads and couplings and in random lengths unless otherwise ordered.

Taper of threads is ¾ inch diameter per foot length for all sizes.

The weight per foot of tubing with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths will usually average less than 20 feet.

All weights given in pounds. All dimensions given in inches.

For general notes see page 21. For test pressures see page 76.

For illustration showing joint see page 82.

California Diamond BX Drive Pipe

All Weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per foot		Threads per inch	Couplings		
	External	Internal		Plain ends	Threads and couplings		Diameter	Length	Weight
4¼	4.750	4.082	.334	15.752	16.000	10	5.357	6⅝	10.112
4½	5.000	4.506	.247	12.538	12.850	10	5.686	6⅛	10.734
4½	5.000	4.424	.288	14.493	15.000	10	5.923	6⅛	14.299

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with threads and couplings and in random lengths unless otherwise ordered. Taper of threads is ⅝ inch diameter per foot length for all sizes.

The weight per foot of pipe with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet. All weights given in pounds. All dimensions given in inches. On sizes made in more than one weight, weight desired must be specified.

For general notes see page 21.

For test pressures see page 76. For illustration showing joint see page 82.

Bedstead Tubing

All Weights and Dimensions are Nominal

Diameters		Thickness	Weight per foot plain ends
External	Internal		
.375	.245	.065	.215
.500	.370	.065	.301
.625	.487	.069	.409
.750	.594	.078	.559
.840	.684	.078	.634
.875	.719	.078	.663
1.000	.844	.078	.768
1.050	.894	.078	.809
1.250	1.072	.089	1.103
1.315	1.137	.089	1.165
1.500	1.310	.095	1.425
1.660	1.470	.095	1.587
1.900	1.682	.109	2.084
2.000	1.782	.109	2.201
2.000	1.760	.120	2.409
2.375	2.115	.130	3.117
2.375	2.107	.134	3.207
2.500	2.232	.134	3.386
2.875	2.509	.183	5.261
3.000	2.670	.165	4.995

The permissible variation in weight is 5 per cent above and 5 per cent below.

This tubing furnished with plain ends pointed tool cut, with surface cleaned for enameling purposes, and cut to any length that may be desired. Bedstead Tubing is not subjected to hydraulic test. All weights given in pounds. All dimensions given in inches. On sizes made in more than one weight, weight or thickness desired must be specified. For general notes see page 21.

Flush Joint Tubing

All Weights and Dimensions are Nominal

Size	Diameters External	Diameters Internal	Thickness	Weight per foot plain ends	Threads per inch	Length of joint "L"
3	3.500	3.068	.216	7.575	14	1¾
3½	4.000	3.548	.226	9.109	14	1¾
4	4.500	4.026	.237	10.790	11½	1¾
4½	5.000	4.506	.247	12.538	11½	1¾
5	5.563	5.047	.258	14.617	11½	2
	6.000	5.440	.280	17.105	11½	2
6	6.625	6.065	.280	18.974	11½	2
	7.000	6.398	.301	21.535	11½	2
7	7.625	7.023	.301	23.544	11½	2
	8.000	7.356	.322	26.404	10	2
8	8.625	7.981	.322	28.554	10	2
	9.000	8.316	.342	31.624	10	2
9	9.625	8.941	.342	33.907	10	2
	10.000	9.270	.365	37.559	10	2¼
10	10.750	10.020	.365	40.483	10	2¼
	12.000	11.250	.375	46.558	10	2¼
12	12.750	12.000	.375	49.562	10	2¼
13	14.000	13.124	.438	63.441	8	2½
14	15.000	14.124	.438	68.119	8	2½
15	16.000	15.000	.500	82.771	8	2½
18 O.D.	18.000	17.000	.500	93.451	8	2½

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished in random lengths unless otherwise ordered.

Taper of threads is ¾16 inch diameter per foot length for all sizes, unless otherwise specified.

Weights lighter than those given in above table are not suitable for flush joints.

All weights given in pounds. All dimensions given in inches.

For general notes see page 21.
For test pressures see page 75.
For illustration showing joint see page 80.

Allison Vanishing Thread Tubing — Ends Upset

All Weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per foot		Threads per inch	O.D. of upset	Couplings		
	External	Internal		Plain ends	Threads and couplings			Diameter	Length	Weight
2	2.375	2.067	.154	3.652	3.731	11½	2 9/16	3.057	3⅝	2.484
2½	2.875	2.469	.203	5.793	5.903	8	3 1/16	3.616	4⅛	3.845
3	3.500	3.068	.216	7.575	7.699	8	3 11/16	4.237	4⅛	4.557
3½	4.000	3.548	.226	9.109	9.287	8	4 3/16	4.848	4⅛	6.036
4	4.500	4.026	.237	10.790	10.984	8	4 11/16	5.345	4⅛	6.768
4½	5.000	4.506	.247	12.538	12.744	8	5 3/16	5.842	4⅛	7.426
5	5.563	5.047	.258	14.617	14.962	8	5¾	6.509	5⅛	11.821
6	6.625	6.065	.280	18.974	19.359	8	6⅞	7.627	5⅛	13.931
7	7.625	7.023	.301	23 544	23.957	8	7⅞	8.621	5⅛	15.778
8	8.625	7.981	.322	28.554	29.196	8	8⅞	9.729	6⅛	24.119

Allison Vanishing Thread Tubing — Not Upset

All Weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per foot		Threads per inch	Couplings		
	External	Internal		Plain ends	Threads and couplings		Diameter	Length	Weight
1¼	1.660	1.380	.140	2.272	2.303	11½	2.070	2⅞	1.052
1½	1.900	1.610	.145	2.717	2.751	11½	2.309	2⅞	1.188
2	2.375	2.067	.154	3.652	3.723	11½	2.870	3⅝	2.315
2½	2.875	2.469	.203	5.793	5.893	8	3.429	4⅛	3.625
3	3.500	3.068	.216	7.575	7.689	8	4.050	4⅛	4.338
3½	4.000	3.548	.226	9.109	9.276	8	4.661	4⅛	5.782
4	4.500	4.026	.237	10.790	10.973	8	5.158	4⅛	6.512
4½	5.000	4.506	.247	12.538	12.733	8	5.655	4⅛	7.171
5	5.563	5.047	.258	14.617	14.946	8	6.322	5⅛	11.456
6	6.625	6.065	.280	18.974	19.338	8	7.377	5⅛	13.446
7	7.625	7.023	.301	23.544	23.936	8	8.371	5⅛	15.296
8	8.625	7.981	.322	28.554	29.167	8	9.479	6⅛	23.465

The following notes apply to both tables.

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with threads and couplings and in random lengths unless otherwise ordered.

Taper of threads is ¾ inch diameter per foot length for all sizes.

The weight per foot of tubing with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet.

All weights given in pounds. All dimensions given in inches.

For general notes see page 21. For test pressures see page 75.

For illustration showing joint see page 81.

Special Rotary Pipe

All Weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per foot		Threads per inch	Couplings		
	External	Internal		Plain ends	Threads and couplings		Diameter	Length	Weight
2½	2.875	2.323	.276	7.661	7.830	8	3.603	5⅛	5.888
2½	2.875	2.143	.366	9.807	10.000	8	3.693	5⅝	7.316
4	4.500	3.958	.271	12.240	12.500	8	5.228	5⅛	8.901
4	4.500	3.826	.337	14.983	15.000	8	5.240	6⅛	11.720
4½	5.000	4.388	.306	15.340	15.500	8	5.604	5⅛	8.270
4½	5.000	4.290	.355	17.611	18.000	8	5.740	6⅛	12.950
5	5.563	4.955	.304	17.074	17.500	8	6.373	6⅛	14.620
5	5.563	4.813	.375	20.778	21.000	8	6.272	7⅛	16.442
6	6.625	5.937	.344	23.076	23.500	8	7.435	6⅛	17.254
6	6.625	5.761	.432	28.573	29.000	8	7.331	7⅛	19.451

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with threads and couplings and in random lengths unless otherwise ordered. Taper of threads is ¾ inch diameter per foot length for all sizes.

The weight per foot of pipe with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet. All weights given in pounds. All dimensions given in inches. On sizes made in more than one weight, weight desired must be specified.

For general notes see page 21. For test pressures see page 76.

For illustration showing joint see page 79.

Special Upset Rotary Pipe

All Weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per foot		Threads per inch	Couplings		
	External	Internal		Plain ends	Threads and couplings		Diameter	Length	Weight
2½	2.875	2.323	.276	7.661	7.841	8	3.564	6⅛	6.743
2½	2.875	2.143	.366	9.807	10.000	8	3.678	6⅛	7.844
4	4.500	3.958	.271	12.240	12.632	8	5.256	7⅝	14.296
4	4.500	3.826	.337	14.983	15.323	8	5.256	7⅝	14.296
5	5.563	4.975	.294	16.544	17.000	8	6.303	8⅛	18.472
5	5.563	4.859	.352	19.590	20.000	8	6.303	8⅛	18.472
6	6.625	6.065	.280	18.974	19.551	8	7.350	8⅝	22.994
6	6.625	5.761	.432	28.573	28.948	8	7.350	8⅝	22.994

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with threads and couplings and in random lengths unless otherwise ordered. Taper of threads is ¾ inch diameter per foot length for all sizes.

The weight per foot of pipe with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet. All weights given in pounds. All dimensions given in inches. On sizes made in more than one weight, weight desired must be specified.

For general notes see page 21. For test pressures see page 76.

For illustration showing joint see page 79.

South Penn Casing

All Weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per foot		Threads per inch	Couplings		
	External	Internal		Plain ends	Threads and couplings		Diameter	Length	Weight
5 3/16	5.500	5.044	.228	12.837	13.000	11½	6.050	4⅝	6.759
5 3/16	5.500	4.892	.304	16.870	17.000	11½	6.050	4⅝	6.759
6¼	6.625	6.257	.184	12.657	13.000	11½	7.280	5⅛	10.630
6¼	6.625	6.135	.245	16.694	17.000	11½	7.280	5⅛	10.630
6⅝	7.000	6.538	.231	16.699	17.000	10	7.642	5⅛	11.133
6⅝	7.000	6.450	.275	19.751	20.000	10	7.642	5⅛	11.133
6⅝	7.000	6.334	.333	23.711	24.000	10	7.699	6⅛	14.458
8¼	8.625	8.097	.264	23.574	24.000	8	9.358	6⅛	18.577
8¼	8.625	8.003	.311	27.615	28.000	8	9.358	6⅛	18.577
10	10.750	10.192	.279	31.201	32.515	8	11.958	6⅝	39.772
10	10.750	10.146	.302	33.699	35.000	8	11.958	6⅝	39.772
12½	13.000	12.278	.361	48.730	50.000	8	14.085	7⅛	46.464

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with threads and couplings and in random lengths unless otherwise ordered. Taper of threads is ⅝ inch diameter per foot length for all sizes, except the 8¼ inch, 10 inch, and 12½ inch which are ¾ inch taper.

The weight per foot of casing with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet. All weights given in pounds. All dimensions given in inches.

On sizes made in more than one weight, weight desired must be specified.

For general notes see page 21. For test pressures see page 71.

For illustration showing joint see page 83.

Reamed and Drifted Pipe

All Weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per foot		Threads per inch	Couplings		
	External	Internal		Plain ends	Threads and couplings		Diameter	Length	Weight
2	2.375	2.067	.154	3.652	3.697	11½	2.773	3⅝	1.806
2	2.375	2.041	.167	3.938	4.000	11½	2.773	3⅝	1.806
2½	2.875	2.469	.203	5.793	5.843	8	3.265	4⅛	2.625
3	3.500	3.068	.216	7.575	7.675	8	4.014	4⅛	4.076
3½	4.000	3.548	.226	9.109	9.261	8	4.628	4⅛	5.510
4	4.500	4.026	.237	10.790	10.980	8	5.233	4⅛	6.673
4½	5.000	4.506	.247	12.538	12.742	8	5.733	4⅛	7.379
5	5.563	5.047	.258	14.617	14.966	8	6.420	5⅛	11.730
6	6.625	6.065	.280	18.974	19.367	8	7.482	5⅛	13.869

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with threads and couplings and in random lengths, 20 feet and shorter, unless otherwise ordered. Taper of threads is ¾ inch diameter per foot length for all sizes. The weight per foot of pipe with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet. On sizes made in more than one weight, weight desired must be specified. All weights given in pounds. All dimensions given in inches. For general notes see page 21. For test pressures see page 73. For illustration showing joint see page 79.

Air Line Pipe

All Weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per foot		Threads per inch	Couplings		
	External	Internal		Plain ends	Threads and couplings		Diameter	Length	Weight
1½	1.900	1.582	.159	2.956	3.00	11½	2.387	2 15/16	1.364
2	2.375	2.043	.166	3.916	4.00	11½	2.976	3½	2.416
2½	2.875	2.423	.226	6.393	6.50	8	3.544	4	3.772
3	3.500	2.990	.255	8.837	9.00	8	4.272	4½	5.899
4	4.500	3.996	.252	11.433	11.75	8	5.500	4½	9.124
5	5.563	4.977	.293	16.491	17.00	8	6.652	6	16.720
6	6.625	6.025	.300	20.265	21.00	8	7.833	6	21.826

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with threads and couplings and in random lengths unless otherwise ordered.

The above pipe is fitted with special air line couplings recessed for lead calking.

Taper of threads is ¾ inch diameter per foot length for all sizes.

The weight per foot of pipe with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet. All weights given in pounds. All dimensions given in inches. For general notes see page 21.

For test pressures see page 73. For illustration showing joint see page 80.

Full Weight Drill Pipe

All Weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per foot		Threads per inch	Couplings		
	External	Internal		Plain ends	Threads and couplings		Diameter	Length	Weight
4	4.500	4.026	.237	10.790	11.055	8	5.228	5⅛	8.901
4	4.500	3.990	.255	11.561	11.815	8	5.228	5⅛	8.901
4½	5.000	4.506	.247	12.538	12.744	8	5.604	5⅛	8.270
5	5.563	5.047	.258	14.617	15.055	8	6.373	6⅛	14.620
6	6.625	6.065	.280	18.974	19.463	8	7.435	6⅛	17.254

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with threads and couplings and in random lengths unless otherwise ordered. Taper of threads is ¾ inch diameter per foot length for all sizes.

The weight per foot of pipe with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet. All weights given in pounds. All dimensions given in inches. On sizes made in more than one weight, weight desired must be specified. For general notes see page 21.

For test pressures see page 76. For illustration showing joint see page 80.

Dry Kiln Pipe

All Weights and Dimensions are Nominal

Size	Diameters: External	Diameters: Internal	Thickness	Weight per foot: Plain ends	Weight per foot: Threads and couplings	Threads per inch	Couplings: Diameter	Couplings: Length	Couplings: Weight
1	1.315	1.049	.133	1.678	1.697	11½	1.700	2⅝	.702
1¼	1.660	1.380	.140	2.272	2.304	11½	2.121	2⅞	1.134

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with threads and couplings and in random lengths unless otherwise ordered.

Taper of threads is ¾ inch diameter per foot length for all sizes.

The weight per foot of pipe with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet.

All weights given in pounds. All dimensions given in inches.

For general notes see page 21.
For test pressures see page 76.
For illustration showing joint see page 83.

Tuyere Pipe

All Weights and Dimensions are Nominal

Size	Diameters: External	Diameters: Internal	Thickness	Weight per foot, plain ends
1	1.315	.957	.179	2.171
1¼	1.660	1.278	.191	2.996

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished with plain ends and in random lengths unless otherwise ordered.

This pipe is made in random lengths up to 40 feet.

All weights given in pounds. All dimensions given in inches.

For general notes see page 21.
For test pressures see page 76.

Locomotive Boiler Tubes — Seamless — Open Hearth Steel

All Weights and Dimensions are Nominal

(For test pressures see page 102.)

Diameters		Thickness		Weight per foot	Length of tube per square foot		Square foot of surface per lineal foot	
External	Internal	Inches	B.W.G.		External surface	Internal surface	External surface	Internal surface
1½	1.310	.095	13	1.425	2.546	2.915	.392	.342
1½	1.282	.109	12	1.619	2.546	2.979	.392	.335
1½	1.280	.110	....	1.632	2.546	2.984	.392	.335
1½	1.260	.120	11	1.768	2.546	3.031	.392	.329
1½	1.250	.125	....	1.835	2.546	3.055	.392	.327
1½	1.232	.134	10	1.954	2.546	3.100	.392	.322
1½	1.230	.135	....	1.968	2.546	3.105	.392	.322
1½	1.204	.148	9	2.137	2.546	3.172	.392	.315
1½	1.200	.150	....	2.162	2.546	3.183	.392	.314
1¾	1.560	.095	13	1.679	2.182	2.448	.458	.408
1¾	1.532	.109	12	1.910	2.182	2.493	.458	.401
1¾	1.530	.110	....	1.926	2.182	2.496	.458	.400
1¾	1.510	.120	11	2.089	2.182	2.529	.458	.395
1¾	1.500	.125	....	2.169	2.182	2.546	.458	.392
1¾	1.482	.134	10	2.312	2.182	2.577	.458	.387
1¾	1.480	.135	....	2.328	2.182	2.580	.458	.387
1¾	1.454	.148	9	2.532	2.182	2.627	.458	.380
1¾	1.450	.150	....	2.563	2.182	2.634	.458	.379
1⅞	1.685	.095	13	1.806	2.037	2.266	.490	.441
1⅞	1.657	.109	12	2.055	2.037	2.305	.490	.433
1⅞	1.655	.110	....	2.073	2.037	2.307	.490	.433
1⅞	1.635	.120	11	2.249	2.037	2.336	.490	.428
1⅞	1.625	.125	....	2.336	2.037	2.350	.490	.425
1⅞	1.607	.134	10	2.491	2.037	2.376	.490	.420
1⅞	1.605	.135	....	2.508	2.037	2 379	.490	.420
1⅞	1.579	.148	9	2.729	2.037	2.419	.490	.413
1⅞	1.575	.150	....	2.763	2.037	2.425	.490	.412
2	1.810	.095	13	1.932	1.909	2.110	.523	.473
2	1.782	.109	12	2.201	1.909	2.143	.523	.466
2	1.780	.110	....	2.220	1.909	2.145	.523	.466
2	1.760	.120	11	2.409	1.909	2.170	.523	.460
2	1.750	.125	....	2.503	1.909	2.182	.523	.458
2	1.732	.134	10	2.670	1.909	2.205	.523	.453

Locomotive Boiler Tubes -- Seamless — Open Hearth Steel (Concluded)

All Weights and Dimensions are Nominal

(For test pressures see page 102.)

Diameters		Thickness		Weight per foot	Length of tube per square foot		Square foot of surface per lineal foot	
External	Internal	Inches	B.W.G.		External surface	Internal surface	External surface	Internal surface
2	1.730	.135	....	2.688	1.909	2.207	.523	.452
2	1.704	.148	9	2.927	1.909	2.241	.523	.446
2	1.700	.150	....	2.963	1.909	2.246	.523	.445
2¼	2.060	.095	13	2.186	1.697	1.854	.589	.539
2¼	2.032	.109	12	2.492	1.697	1.879	.589	.531
2¼	2.030	.110	....	2.514	1.697	1.881	.589	.531
2¼	2.010	.120	11	2.729	1.697	1.900	.589	.526
2¼	2.000	.125	....	2.836	1.697	1.909	.589	.523
2¼	1.982	.134	10	3.028	1.697	1.927	.589	.518
2¼	1.980	.135	....	3.049	1.697	1.929	.589	.518
2¼	1.954	.148	9	3.322	1.697	1.954	.589	.511
2¼	1.950	.150	....	3.364	1.697	1.958	.589	.510
2½	2.310	.095	13	2.440	1.527	1.653	.654	.604
2½	2.282	.109	12	2.783	1.527	1.673	.654	.597
2½	2.280	.110	....	2.807	1.527	1.675	.654	.596
2½	2.260	.120	11	3.050	1.527	1.690	.654	.591
2½	2.250	.125	....	3.170	1.527	1.697	.654	.589
2½	2.232	.134	10	3.386	1.527	1.711	.654	.584
2½	2.230	.135	....	3.409	1.527	1.712	.654	.583
2½	2.204	.148	9	3.717	1.527	1.733	.654	.577
2½	2.200	.150	....	3.764	1.527	1.736	.654	.575
3	2.810	.095	13	2.947	1.273	1.359	.785	.735
3	2.782	.109	12	3.365	1.273	1.373	.785	.728
3	2.780	.110	....	3.395	1.273	1.374	.785	.727
3	2.760	.120	11	3.691	1.273	1.383	.785	.722
3	2.750	.125	....	3.838	1.273	1.388	.785	.719
3	2.732	.134	10	4.101	1.273	1.398	.785	.715
3	2.730	.135	....	4.130	1.273	1.399	.785	.714
3	2.704	.148	9	4.508	1.273	1.412	.785	.707
3	2.700	.150	....	4.565	1.273	1.414	.785	.706

Locomotive Boiler Tubes — Lap Welded — Open Hearth Steel

All Weights and Dimensions are Nominal

(For test pressures see page 72.)

Diameters		Thickness		Weight per foot	Length of tube per square foot		Square foot of surface per lineal foot	
External	Internal	Inches	B.W.G.		External surface	Internal surface	External surface	Internal surface
1¾	1.560	.095	13	1.679	2.182	2.448	.458	.408
1¾	1.532	.109	12	1.910	2.182	2.493	.458	.401
1¾	1.530	.110	....	1.926	2.182	2.496	.458	.400
1¾	1.510	.120	11	2.089	2.182	2.529	.458	.395
1¾	1.500	.125	....	2.169	2.182	2.546	.458	.392
1¾	1.482	.134	10	2.312	2.182	2.577	.458	.387
1¾	1.480	.135	....	2.328	2.182	2.580	.458	.387
1¾	1.454	.148	9	2.532	2.182	2.627	.458	.380
1¾	1.450	.150	....	2.563	2.182	2.634	.458	.379
2	1.810	.095	13	1.932	1.909	2.110	.523	.473
2	1.782	.109	12	2.201	1.909	2.143	.523	.466
2	1.780	.110	....	2.220	1.909	2.145	.523	.466
2	1.760	.120	11	2.409	1.909	2.170	.523	.460
2	1.750	.125	....	2.503	1.909	2.182	.523	.458
2	1.732	.134	10	2.670	1.909	2.205	.523	.453
2	1.730	.135	....	2.688	1.909	2.207	.523	.452
2	1.704	.148	9	2.927	1.909	2.241	.523	.446
2	1.700	.150	....	2.963	1.909	2.246	.523	.445
2¼	2.060	.095	13	2.186	1.697	1.854	.589	.539
2¼	2.032	.109	12	2.492	1.697	1.879	.589	.531
2¼	2.030	.110	....	2.514	1.697	1.881	.589	.531
2¼	2.010	.120	11	2.729	1.697	1.900	.589	.526
2¼	2.000	.125	....	2.836	1.697	1.909	.589	.523
2¼	1.982	.134	10	3.028	1.697	1.927	.589	.518
2¼	1.980	.135	....	3.049	1.697	1.929	.589	.518
2¼	1.954	.148	9	3.322	1.697	1.954	.589	.511
2¼	1.950	.150	....	3.364	1.697	1.958	.589	.510
2½	2.310	.095	13	2.440	1.527	1.653	.654	.604
2½	2.282	.109	12	2.783	1.527	1.673	.654	.597
2½	2.280	.110	....	2.807	1.527	1.675	.654	.596
2½	2.260	.120	11	3.050	1.527	1.690	.654	.591
2½	2.250	.125	....	3.170	1.527	1.697	.654	.589
2½	2.232	.134	10	3.386	1.527	1.711	.654	.584
2½	2.230	.135	....	3.409	1.527	1.712	.654	.583
2½	2.204	.148	9	3.717	1.527	1.733	.654	.577
2½	2.200	.150	....	3.764	1.527	1.736	.654	.575
3	2.810	.095	13	2.947	1.273	1.359	.785	.735
3	2.782	.109	12	3.365	1.273	1.373	.785	.728
3	2.780	.110	....	3.395	1.273	1.374	.785	.727
3	2.760	.120	11	3.691	1.273	1.383	.785	.722
3	2.750	.125	....	3.838	1.273	1.388	.785	.719
3	2.732	.134	10	4.101	1.273	1.398	.785	.715
3	2.730	.135	....	4.130	1.273	1.399	.785	.714
3	2.704	.148	9	4.508	1.273	1.412	.785	.707
3	2.700	.150	....	4.565	1.273	1.414	.785	.706

Standard Boiler Tubes and Flues — Lap Welded

All Weights and Dimensions are Nominal

(For test pressures see page 72.)

Diameters		Thickness		Weight per foot	Length of tube per square foot		Square feet of surface per lineal foot	
External	Internal	Inches	B.W.G.		External surface	Internal surface	External surface	Internal surface
1¾	1.560	.095	13	1.679	2.182	2.448	.458	.408
2	1.810	.095	13	1.932	1.909	2.110	.523	.473
2¼	2.060	.095	13	2.186	1.697	1.854	.589	.539
2½	2.282	.109	12	2.783	1.527	1.673	.654	.597
2¾	2.532	.109	12	3.074	1.388	1.508	.719	.662
3	2.782	.109	12	3.365	1.273	1.373	.785	.728
3¼	3.010	.120	11	4.011	1.175	1.269	.850	.788
3½	3.260	.120	11	4.331	1.091	1.171	.916	.853
3¾	3.510	.120	11	4.652	1.018	1.088	.981	.918
4	3.732	.134	10	5.532	.954	1.023	1.047	.977
4½	4.232	.134	10	6.248	.848	.902	1.178	1.107
5	4.704	.148	9	7.669	.763	.812	1.308	1.231
6	5.670	.165	8	10.282	.636	.673	1.570	1.484
7	6.670	.165	8	12.044	.545	.572	1.832	1.746
8	7.670	.165	8	13.807	.477	.498	2.094	2.008
9	8.640	.180	7	16.955	.424	.442	2.356	2.261
10	9.594	.203	6	21.240	.381	.398	2.617	2.511
11	10.560	.220	5	25.329	.347	.361	2.879	2.764
12	11.542	.229	..	28.788	.318	.330	3.141	3.021
13	12.524	.238	4	32.439	.293	.304	3.403	3.278
14	13.504	.248	..	36.424	.272	.282	3.665	3.535
15	14.482	.259	3	40.775	.254	.263	3.926	3.791
16	15.460	.270	..	45.359	.238	.247	4.188	4.047

Matheson Joint Pipe

All Weights and Dimensions are Nominal

External diameter	Thickness	Outside diameter of reinforcing ring — *D*	Length of joint — *L*	Weight per foot		Weight of lead per joint
				Plain ends	Complete	
2.00	.095	2.966	2.16	1.932	1.952	1.00
3.00	.109	4.034	2.26	3.365	3.392	1.75
4.00	.128	5.236	2.32	5.293	5.339	2.75
5.00	.134	6.268	2.38	6.963	7.019	3.50
6.00	.140	7.446	2.50	8.762	8.872	4.75
7.00	.149	8.484	2.58	10.902	11.028	5.50
8.00	.158	9.646	2.73	13.233	13.405	6.75
8 00	.185	9.700	2.78	15.441	15.614	6.75
9.00	.167	10.684	2.73	15.754	15.945	8.25
9.00	.196	10.742	2.90	18.429	18.621	8.50
9.00	.250	10.850	3.07	23.362	23.557	9.00
10.00	.175	11.846	2.82	18.363	18.610	9.50
10.00	.208	11.912	2.85	21.752	22.001	9.75
10.00	.270	12.036	3.06	28.057	28.309	10.00
11.00	.185	12.886	2.91	21.368	21.638	11.00
11.00	.220	12.956	2.93	25.329	25.600	11.00
11.00	.290	13.096	3.17	33.171	33.445	12.50
12.00	.194	14.048	3.00	24.461	24.880	13.25
12.00	.244	14.148	3.40	30.635	31.057	14.25
12.00	.310	14.280	3.76	38.703	39.129	16.50
13.00	.202	15.084	3.07	27.610	28.060	15.25
13.00	.247	15.174	3.40	33.642	34.095	15.50
13.00	.310	15.300	3.76	42.014	42.472	18.00
14.00	.210	16.370	3.15	30.928	31.536	17.25
14.00	.250	16.450	3.53	36.713	37.324	19.25
14.00	.310	16.570	3.84	45.325	45.941	20.75
15.00	.222	17.394	3.24	35.038	35.686	19.25
15.00	.260	17.470	3.53	40.930	41.581	20.25
15.00	.320	17.590	3.84	50.171	50.826	22.25
16.00	.234	18.438	3.32	39.401	40.089	22.00
16.00	.270	18.510	3.62	45.359	46.050	23.25
16.00	.330	18.630	3.75	55.228	55.923	24.25
17.00	.240	19.470	3.41	42.959	43.687	23.75
18.00	.245	20.730	3.50	46.458	47.384	25.75
18.00	.310	20.860	3.87	58.568	59.501	28.50
19.00	.259	21.778	3.57	51.840	52.815	29.00
20.00	.272	22.804	3.64	57.309	58.332	31.00
20.00	.375	23.010	4.17	78.599	79.631	35.50
22.00	.301	24.882	4.06	69.756	71.098	40.25
22.00	.400	25.080	4.65	92.276	93.629	45.50
24.00	.330	26.980	4.26	83.423	84.882	48.00
26.00	.362	29.064	4.40	99.122	100.697	55.25
28.00	.396	31.672	4.58	116.746	119.021	65.00
30.00	.432	33.764	4.75	136.421	138.851	75.00

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished in random lengths unless otherwise ordered. The weight per foot complete is based on a length of 18 feet of pipe, but shipping lengths of small sizes will usually average less than 18 feet. On sizes made in more than one weight, weight desired must be specified. Column marked weight complete includes the ring but not the lead. Pipe furnished black, galvanized, or dipped. Lead not furnished. All weights given in pounds. All dimensions given in inches. For general notes see page 21. For list of test pressures see page 73. For illustration showing joint see page 84.

Converse Lock-joint Pipe

All Weights and Dimensions are Nominal

External diameter	Thickness	Weight per foot plain ends	Hub — cast iron: Diameter D	Hub — cast iron: Length L	Hub — cast iron: Weight	Weight of lead for field end	Weight per foot complete including hub leaded on mill end
2.00	.095	1.932	3¾	3½	4.25	1.00	2.207
3.00	.109	3.365	5⅛	3¾	8.50	2.25	3.931
4.00	.128	5.293	6¼	4	10.50	3.00	5.991
5.00	.134	6.963	7¼	4¼	15.00	3.75	7.932
6.00	.140	8.762	8¼	4½	19.00	4.50	9.969
7.00	.149	10.902	9½	4½	24.00	5.50	12.419
8.00	.158	13.233	10½	4¾	28.25	6.50	15.008
8.00	.185	15.441	10½	4¾	28.25	6.50	17.190
9.00	.167	15.754	11¾	4¾	34.50	8.50	17.958
9.00	.196	18.429	11¾	4¾	34.50	8.50	20.602
9.00	.250	23.362	11¾	4¾	34.50	8.50	25.477
10.00	.175	18.363	12¾	5	39.00	9.00	20.801
10.00	.208	21.752	12¾	5	39.00	9.00	24.148
10.00	.270	28.057	12¾	5	39.00	9.00	30.375
11.00	.185	21.368	13¾	5	41.50	10.00	23.963
11.00	.220	25.329	13¾	5	41.50	10.00	27.875
11.00	.290	33.171	13¾	5	41.50	10.00	35.619
12.00	.194	24.461	15	5½	55.00	11.00	27.795
12.00	.244	30.635	15	5½	55.00	11.00	33.885
12.00	.310	38.703	..	5½	55.00	11.00	41.844
13.00	.202	27.610		5½	59.00	12.00	31.179
13.00	.247	33.642		5½	59.00	12.00	37.129
13.00	.310	42.014		5½	59.00	12.00	45.387
14.00	.210	30.928		5¾	67.00	14.50	35.013
14.00	.250	36.713		5¾	67.00	14.50	40.714
14.00	.310	45.325		5¾	67.00	14.50	49.204
15.00	.222	35.038		5¾	78.00	15.50	39.731
15.00	.260	40.930		5¾	78.00	15.50	45.538
15.00	.320	50.171		5¾	78.00	15.50	54.646
16.00	.234	39.401		6¼	102.00	25.00	45.847
16.00	.270	45.359		6¼	102.00	25.00	51.713
16.00	.330	55.228		6¼	102.00	25.00	61.428
17.00	.240	42.959		6¼	110.00	26.00	49.850
18.00	.245	46.458		6¾	140.00	30.00	55.123
18.00	.310	58.568		6¾	140.00	30.00	67.030
19.00	.259	51.840		6¾	150.00	32.00	61.081
20.00	.272	57.309		7¼	180.00	37.00	68.337
20.00	.375	78.509		7¼	180.00	37.00	89.244
22.00	.301	69.756		7¾	215.00	45.00	82.868
22.00	.400	92.276	[illegible]	7¾	215.00	45.00	104.958
24.00	.330	83.423	29	8¼	275.00	50.00	99.789
26.00	.362	99.122	31⅝	8¾	360.00	64.00	120.555
28.00	.396	116.746	33 15/16	9¼	425.00	77.00	142.000
30.00	.432	136.421	36 5/16	10	525.00	82.00	166.828

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished in random lengths unless otherwise ordered. The weight per foot complete is based on a length of 18 feet, including the hub, but shipping lengths of small sizes will usually average less than 18 feet. On sizes made in more than one weight, weight desired must be specified. Pipe furnished black, galvanized, or dipped. Lead for field end not furnished. All weights given in pounds.

All dimensions given in inches. For general notes see page 21. For list of test pressures see page 74. For illustration showing joint see page 84.

Kimberley Joint Pipe

All Weights and Dimensions are Nominal

External diameter	Thickness	Weight per foot: Plain ends	Weight per foot: Complete excluding lead	Collar: Diameter D	Collar: Length L	Collar: Weight	Weight of lead required
6.00	.140	8.762	9.623	7.63	6	15.50	10.00
7.00	.149	10.902	11.930	8.64	6	18.50	13.50
8.00	.158	13.233	14.371	9.65	6	20.50	15.50
8.00	.185	15.441	16.579	9.65	6	20.50	15.50
9.00	.167	15.754	17.032	10.65	6	23.00	17.25
9.00	.196	18.429	19.707	10.65	6	23.00	17.25
9.00	.250	23.362	24.640	10.65	6	23.00	17.25
10.00	.175	18.363	19.779	11.66	6	25.50	19.00
10.00	.208	21.752	23.169	11.66	6	25.50	19.00
10.00	.270	28.057	29.474	11.66	6	25.50	19.00
11.00	.185	21.368	22.924	12.67	6	28.00	23.25
11.00	.220	25.329	26.884	12.67	6	28.00	23.25
11.00	.290	33.171	34.727	12.67	6	28.00	23.25
12.00	.194	24.461	26.128	13.67	6	30.00	25.50
12.00	.244	30.635	32.302	13.67	6	30.00	25.50
12.00	.310	38.703	40.370	13.67	6	30.00	25.50
13.00	.202	27.610	29.443	14.68	6	33.00	27.50
13.00	.247	33.642	35.475	14.68	6	33.00	27.50
13.00	.310	42.014	43.848	14.68	6	33.00	27.50
14.00	.210	30.928	32.873	15.68	6	35.00	29.50
14.00	.250	36.713	38.657	15.68	6	35.00	29.50
14.00	.310	45.325	47.269	15.68	6	35.00	29.50
15.00	.222	35.038	37.094	16.69	6	37.00	31.50
15.00	.260	40.930	42.986	16.69	6	37.00	31.50
15.00	.320	50.171	52.226	16.69	6	37.00	31.50
16.00	.234	39.401	41.596	17.70	6	39.50	34.36
16.00	.270	45.359	47.554	17.70	6	39.50	34.36
16.00	.330	55.228	57.422	17.70	6	39.50	34.36
17.00	.240	42.959	47.737	19.06	9	86.00	64.00
18.00	.245	46.458	51.486	20.07	9	90.50	69.00
18.00	.310	58.568	63.596	20.07	9	90.50	69.00
19.00	.259	51.840	57.118	21.07	9	95.00	72.50
20.00	.272	57.309	62.865	22.08	9	100.00	78.00
20.00	.375	78.599	84.154	22.08	9	100.00	78.00
22.00	.301	69.756	75.839	24.09	9	109.50	89.50
22.00	.400	92.276	98.359	24.09	9	109.50	89.50
24.00	.330	83.423	90.034	26.11	9	119.00	97.50
26.00	.362	99.122	106.260	28.12	9	128.50	105.50
28.00	.396	116.746	124.413	30.13	9	138.00	113.50
30.00	.432	136.421	144.616	32.14	9	147.50	121.50

The permissible variation in weight is 5 per cent above and 5 per cent below.

Furnished in random lengths unless otherwise ordered.

The weight per foot complete excluding lead is based on a length of 18 feet of pipe, but shipping lengths of small sizes will usually average less than 18 feet.

On sizes made in more than one weight, weight desired must be specified.

Pipe furnished black, galvanized, or dipped. Collars are shipped loose, to be put on in field. Weight of lead specified is for a complete joint, both sides of collar.

Lead not furnished. All weights given in pounds All dimensions given in inches.

For general notes see page 21. For list of test pressures see page 74.
For illustration showing joint see page 83.

Square Pipe

All Weights and Dimensions are Nominal

Size: External	Size: Internal	Thickness	Weight per foot plain ends
7/8	.607	.134	1.46
1	.800	.100	1.25
1	.750	.125	1.55
1	.624	.188	2.11
1¼	1.000	.125	1.97
1¼	.982	.134	2.05
1¼	.938	.156	2.29
1¼	.874	.188	2.48
1¼	.750	.250	3.28
1½	1.250	.125	2.33
1½	1.220	.140	2.55
1½	1.188	.156	2.78
1½	1.124	.188	3.05
1½	1.000	.250	4.00
1 11/16	1.407	.140	2.76
1 11/16	1.375	.156	3.00
1 11/16	1.311	.188	3.75
1 11/16	1.187	.250	4.60
2	1.750	.125	3.10
2	1.732	.134	3.18
2	1.710	.145	3.52
2	1.624	.188	4.39
2	1.500	.250	5.40
2½	2.124	.188	5.60
3	2.600	.200	7.06

Rectangular Pipe

All Weights and Dimensions are Nominal

Size: External	Size: Internal	Thickness	Weight per foot plain ends
1¼×1	.970× .720	.140	1.67
1¼×1	.874× .624	.188	2.05
1½×1¼	1.256×1.006	.122	2.05
1½×1¼	1.210× .960	.145	2.24
1½×1¼	1.188× .938	.156	2.40
1½×1¼	1.124× .874	.188	2.85
1½×1¼	1.000× .750	.250	3.67
2 ×1¼	1.732× .982	.134	2.53
2 ×1½	1.710×1.210	.145	3.00
2 ×1½	1.624×1.124	.188	3.61
2 ×1½	1.500×1.000	.250	4.65
2½×1½	2.210×1.210	.145	3.52
2½×1½	2.124×1.124	.188	4.39
2½×1½	2.000×1.000	.250	5.40
3 ×2	2.624×1.624	.188	5.60
3 ×2	2.600×1.600	.200	6.00

The following notes apply to both tables.

The permissible variation in weight is 5 per cent above and 5 per cent below. Cut to any length that may be desired. All weights given in pounds. All dimensions given in inches. For sections see pages 85–88. On sizes made in more than one weight, weight or thickness desired must be specified.

For general notes see page 21.

Weight per Foot of Pipe (Nominal Inside Diameter)

Inside diameter	Birmingham Wire Gage 16		15	14		13		12	11	
	Fractions and decimals of an inch									
	.065	.068	.072	.083	3/32 .09375	.095	.100	.109	.120	1/8 .125
1/8	.236	.244	.256	.285	.311	.314	.325	.344	.365	.373
1/4	.....	.....	.359	.405	.446	.451	.469	.501	.538	.554
3/8	.....	.....	.463	.524	.581	.588	.614	.658	.711	.734
1/2	.....	.....	.590	.671	.747	.755	.790	.850	.922	.954
3/4	.....	.....	.752	.857	.957	.968	1.014	1.095	1.191	1.234
1	.....	.....	.....	.....	1.222	1.237	1.297	1.403	1.531	1.588
1 1/4	.....	.....	.....	.....	1.568	1.587	1.666	1.805	1.973	2.049
1 1/2	.....	.....	.....	.....	.....	1.831	1.922	2.084	2.281	2.369
2	.....	.....	.....	.....	.....	2.313	2.429	2.637	2.890	3.003
2 1/2	.....	.....	.....	.....	.....	.....	.....	3.220	3.530	3.671
3	.....	.....	.....	.....	.....	.....	.....	3.947	4.331	4.505
3 1/2	.....	.....	.....	.....	.....	.....	.....	.....	.....	5.173
4	.....	.....	.....	.....	.....	.....	.....	.....	.....	5.840
4 1/2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Inside diameter	Birmingham Wire Gage 6		5	4		3		2
	Fractions and decimals of an inch							
	.203	7/32 .21875	.220	.238	1/4 .250	.259	9/32 .28125	.284
1/8								
1/4	.730	.750	.751					
3/8	1.023	1.065	1.069	1.110	1.134	1.150		
1/2	1.381	1.451	1.456	1.530	1.575	1.607	1.678	1.686
3/4	1.836	1.942	1.950	2.064	2.136	2.188	2.309	2.323
1	2.410	2.561	2.572	2.737	2.843	2.921	3.105	3.127
1 1/4	3.158	3.367	3.383	3.614	3.764	3.875	4.141	4.173
1 1/2	3.679	3.927	3.947	4.224	4.405	4.539	4.862	4.901
2	4.709	5.037	5.063	5.431	5.673	5.853	6.289	6.342
2 1/2	5.793	6.205	6.238	6.702	7.008	7.236	7.791	7.858
3	7.148	7.665	7.706	8.291	8.677	8.965	9.668	9.754
3 1/2	8.232	8.834	8.881	9.562	10.012	10.348	11.170	11.271
4	9.316	10.002	10.056	10.833	11.347	11.731	12.672	12.787
4 1/2	10.400	11.170	11.231	12.104	12.682	13.114	14.174	14.304
5	11.620	12.485	12.554	13.535	14.185	14.671	15.865	16.012
6	13.923	14.966	15.049	16.234	17.021	17.609	19.055	19.233
7	16.091	17.303	17.399	18.776	19.691	20.375	22.059	22.266
8	18.259	19.639	19.748	21.318	22.361	23.141	25.062	25.299
9	20.427	21.975	22.098	23.860	25.031	25.907	28.066	28.332
10	22.866	24.604	24.741	26.720	28.035	29.019	31.445	31.745
11	25.034	26.940	27.091	29.262	30.705	31.785	34.449	34.778
12	27.202	29.276	29.440	31.803	33.375	34.552	37.453	37.811

Weight per Foot of Pipe (Nominal Inside Diameter) (Continued)

Inside diameter	Birmingham Wire Gage							
	10	9			8	7		
	Fractions and decimals of an inch							
	.134	.148	.150	5/32 .15625	.165	.180	3/16 .1875	.200
1/8	.387	.406	.408					
1/4	.581	.619	.624	.640	.660	.692	.705	.726
3/8	.774	.833	.841	.865	.898	.951	.976	1.014
1/2	1.010	1.093	1.105	1.141	1.189	1.268	1.306	1.367
3/4	1.310	1.425	1.441	1.491	1.559	1.672	1.727	1.815
1	1.690	1.844	1.866	1.933	2.026	2.181	2.257	2.381
1 1/4	2.183	2.389	2.419	2.509	2.634	2.845	2.948	3.118
1 1/2	2.527	2.769	2.803	2.909	3.057	3.306	3.429	3.631
2	3.207	3.520	3.564	3.702	3.894	4.219	4.380	4.645
2 1/2	3.922	4.310	4.365	4.536	4.775	5.180	5.381	5.713
3	4.817	5.298	5.366	5.579	5.877	6.382	6.633	7.048
3 1/2	5.532	6.088	6.167	6.414	6.758	7.343	7.634	8.116
4	6.248	6.879	6.968	7.248	7.639	8.304	8.635	9.184
4 1/2	6.963	7.669	7.769	8.083	8.520	9.266	9.637	10.252
5	7.769	8.559	8.671	9.022	9.512	10.348	10.764	11.455
6	......	10.237	10.373	10.794	11.383	12.390	12.891	13.724
7	......	11.818	11.975	12.463	13.146	14.312	14.893	15.860
8	......	......	......	14.132	14.908	16.234	16.896	17.996
9	......	......	......	......	16.670	18.157	18.898	20.132
10	......	......	......	......	......	20.320	21.151	22.535
11	......	......	......	......	......	......	23.154	24.671
12	......	......	......	......	......	......	......	26.807

Inside diameter	Birmingham Wire Gage							
	1		0				00	
	Fractions and decimals of an inch							
	.300	5/16 .3125	.340	11/32 .34375	.350	3/8 .375	.380	.400
1/8								
1/4								
3/8								
1/2	1.730							
3/4	2.403	2.461	2.578	2.592	2.616	2.703		
1	3.252	3.345	3.540	3.565	3.607	3.764	3.794	
1 1/4	4.357	4.497	4.793	4.832	4.896	5.146	5.194	5.382
1 1/2	5.126	5.298	5.664	5.713	5.793	6.107	6.168	6.408
2	6.648	6.883	7.389	7.457	7.569	8.010	8.096	8.437
2 1/2	8.250	8.552	9.205	9.292	9.438	10.012	10.125	10.573
3	10.252	10.638	11.474	11.587	11.774	12.515	12.662	13.243
3 1/2	11.854	12.307	13.290	13.423	13.643	14.518	14.691	15.379
4	13.457	13.975	15.106	15.258	15.512	16.520	16.720	17.515
4 1/2	15.059	15.644	16.921	17.094	17.381	18.523	18.750	19.651
5	16.862	17.523	18.966	19.161	19.486	20.778	21.034	22.056
6	20.265	21.068	22.822	23.060	23.456	25.031	25.345	26.593
7	23.469	24.405	26.453	26.731	27.194	29.036	29.403	30.865
8	26.673	27.743	30.084	30.402	30.932	33.041	33.462	35.137
9	29.877	31.080	33.716	34.074	34.670	37.046	37.520	39.409
10	33.482	34.835	37.801	38.204	38.875	41.552	42.086	44.215
11	36.686	38.173	41.432	41.875	42.613	45.557	46.144	48.487
12	39.890	41.510	45.063	45.547	46.351	49.562	50.203	52.759

Weight per Foot of Pipe (Nominal Inside Diameter) (Continued)

Inside diameter	Birmingham Wire Gage							
		000			0000			
	Fractions and decimals of an inch							
	13/32 .40625	.425	7/16 .4375	.450	.454	15/32 .46875	1/2 .500	.550
1/8								
1/4								
3/8								
1/2								
3/4								
1								
1 1/4	5.439	5.605	5.712	5.815	5.847	5.963	6.194	6.520
1 1/2	6.481	6.695	6.833	6.968	7.011	7.165	7.476	7.930
2	8.542	8.851	9.053	9.251	9.314	9.543	10.012	10.720
2 1/2	10.711	11.120	11.389	11.654	11.738	12.046	12.682	13.657
3	13.423	13.957	14.309	14.658	14.769	15.175	16.020	17.328
3 1/2	15.592	16.227	16.646	17.061	17.193	17.678	18.690	20.265
4	17.762	18.496	18.982	19.464	19.618	20.181	21.360	23.202
4 1/2	19.931	20.766	21.318	21.867	22.042	22.684	24.030	26.139
5	22.374	23.321	23.949	24.573	24.772	25.503	27.036	29.446
6	26.982	28.142	28.911	29.677	29.921	30.820	32.707	35.685
7	31.320	32.681	33.584	34.483	34.770	35.826	38.048	41.559
8	35.659	37.220	38.256	39.289	39.619	40.832	43.388	47.433
9	39.998	41.759	42.929	44.095	44.468	45.839	48.728	53.307
10	44.879	46.865	48.185	49.502	49.923	51.471	54.735	59.915
11	49.218	51.404	52.858	54.308	54.771	56.477	60.075	65.789
12	53.557	55.944	57.531	59.114	59.620	61.483	65.415	71.663

Weight per Foot of Pipe (Nominal Inside Diameter) (Concluded)

Inside diameter	Fractions and decimals of an inch						
	9/16 .5625	.600	5/8 .625	.650	11/16 .6875	.700	3/4 .750
1/8							
1/4							
3/8							
1/2							
3/4							
1							
1 1/4							
1 1/2	8.035	8.330	8.510	8.677	8.902		
2	10.888	11.374	11.681	11.975	12.390	12.522	13.016
2 1/2	13.892	14.578	15.018	15.446	16.061	16.260	17.021
3	17.647	18.583	19.190	19.784	20.651	20.933	22.027
3 1/2	20.651	21.787	22.528	23.256	24.322	24.671	26.032
4	23.654	24.991	25.866	26.727	27.993	28.409	30.037
4 1/2	26.658	28.195	29.203	30.198	31.665	32.147	34.043
5	30.040	31.803	32.961	34.106	35.798	36.356	38.552
6	36.421	38.608	40.050	41.479	43.596	44.295	47.059
7	42.428	45.016	46.725	48.421	50.939	51.772	55.069
8	48.436	51.424	53.400	55.363	58.281	59.248	63.079
9	54.443	57.833	60.075	62.305	65.624	66.724	71.089
10	61.202	65.042	67.585	70.115	73.885	75.134	80.101
11	67.209	71.450	74.260	77.057	81.227	82.611	88.111
12	73.217	77.858	80.935	83.999	88.570	90.087	96.121

Inside diameter	Fractions and decimals of an inch						
	.800	13/16 .8125	.850	7/8 .875	.900	15/16 .9375	1
1/8							
1/4							
3/8							
1/2							
3/4							
1							
1 1/4							
1 1/2							
2	13.457	13.558	13.844	14.017			
2 1/2	17.729	17.897	18.383	18.690			
3	23.069	23.321	24.057	24.530	24.991	25.657	26.700
3 1/2	27.341	27.659	28.596	29.203	29.797	30.663	32.040
4	31.613	31.998	33.135	33.876	34.603	35.670	37.380
4 1/2	35.885	36.337	37.674	38.548	39.409	40.676	42.720
5	40.695	41.223	42.785	43.810	44.821	46.313	48.733
6	49.769	50.438	52.426	53.734	55.029	56.946	60.075
7	58.313	59.116	61.504	63.079	64.641	66.959	70.756
8	66.857	67.793	70.582	72.424	74.253	76.972	81.436
9	75.401	76.471	79.660	81.769	83.865	86.984	92.116
10	85.014	86.233	89.873	92.283	94.679	98.249	104.131
11	93.558	94.911	98.951	101.628	104.291	108.261	114.811
12	102.102	103.589	108.029	110.973	113.903	118.274	125.491

Weight per Foot of Tubes (or Outside Diameter Pipe)

Outside diameter	Birmingham Wire Gage									
	15	14		13		12	11		10	9
	Fractions and decimals of an inch									
	.072	.083	3/32 .09375	.095	.100	.109	.120	1/8 .125	.134	.148
1.000	.713	.812	.907	.918	.961	1.037	1.127	1.168	1.239	1.346
1.125	.....	.923	1.032	1.045	1.094	1.182	1.288	1.335	1.418	1.544
1.250	.....	1.034	1.157	1.171	1.228	1.328	1.448	1.501	1.597	1.741
1.312	.....	1.089	1.219	1.234	1.294	1.400	1.527	1.584	1.685	1.839
1.375	.....	.....	1.282	1.298	1.361	1.473	1.608	1.668	1.776	1.939
1.500	.....	.....	.....	1.425	1.495	1.619	1.768	1.835	1.954	2.137
1.625	.....	.....	.....	1.552	1.628	1.764	1.928	2.002	2.133	2.334
1.750	.....	.....	.....	1.679	1.762	1.910	2.089	2.169	2.312	2.532
1.875	.....	.....	.....	1.806	1.895	2.055	2.249	2.336	2.491	2.729
2.000	.....	.....	.....	1.932	2.029	2.201	2.409	2.503	2.670	2.927
2.125	.....	.....	.....	2.059	2.162	2.346	2.569	2.670	2.849	3.124
2.250	.....	.....	.....	2.186	2.296	2.492	2.729	2.836	3.028	3.322
2.500	.....	.....	.....	2.440	2.563	2.783	3.050	3.170	3.386	3.717
2.750	.....	.....	.....	2.693	2.830	3.074	3.370	3.504	3.743	4.112
3.000	.....	.....	.....	2.947	3.097	3.365	3.691	3.838	4.101	4.508
3.250	.....	.....	.....	.....	.....	3.656	4.011	4.171	4.459	4.903
3.500	.....	.....	.....	.....	.....	3.947	4.331	4.505	4.817	5.298
3.750	.....	.....	.....	.....	.....	.....	4.652	4.839	5.175	5.693
4.000	.....	.....	.....	.....	.....	.....	.....	5.173	5.532	6.088
4.250	.....	.....	.....	.....	.....	.....	.....	5.506	5.890	6.483
4.500	.....	.....	.....	.....	.....	.....	.....	5.840	6.248	6.879
4.750	.....	.....	.....	.....	.....	.....	.....	.....	6.606	7.274
5.000	.....	.....	.....	.....	.....	.....	.....	.....	6.963	7.669
5.250	.....	.....	.....	.....	.....	.....	.....	.....	7.321	8.064
5.500	.....	.....	.....	.....	.....	.....	.....	.....	7.679	8.459
6.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	9.250
7.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	10.830
8.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
13.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
14.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
15.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
16.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
17.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
18.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
19.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
21.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
22.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
24.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
26.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
28.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30.000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Weight per Foot of Tubes (or Outside Diameter Pipe) (Continued)

Outside diameter	Birmingham Wire Gage							
			8	7			6	
	Fractions and decimals of an inch							
	.150	5/32 .15625	.165	.180	3/16 .1875	.200	.203	7/32 .21875
1.000	1.361	1.408	1.471	1.576	1.627	1.708	1.727	1.825
1.125	1.561	1.616	1.691	1.816	1.877	1.975	1.998	2.117
1.250	1.762	1.825	1.912	2.056	2.127	2.242	2.269	2.409
1.312	1.861	1.928	2.021	2.176	2.251	2.375	2.404	2.554
1.375	1.962	2.033	2.132	2.297	2.378	2.509	2.540	2.701
1.500	2.162	2.242	2.352	2.537	2.628	2.776	2.811	2.993
1.625	2.362	2.451	2.572	2.777	2.878	3.043	3.082	3.285
1.750	2.563	2.659	2.793	3.018	3.128	3.310	3.354	3.577
1.875	2.763	2.868	3.013	3.258	3.379	3.577	3.625	3.869
2.000	2.963	3.076	3.233	3.498	3.629	3.844	3.896	4.161
2.125	3.163	3.285	3.453	3.739	3.879	4.111	4.167	4.453
2.250	3.364	3.493	3.674	3.979	4.130	4.378	4.438	4.745
2.500	3.764	3.911	4.114	4.460	4.630	4.912	4.980	5.329
2.750	4.165	4.328	4.555	4.940	5.131	5.446	5.522	5.913
3.000	4.565	4.745	4.995	5.421	5.632	5.980	6.064	6.497
3.250	4.966	5.162	5.436	5.901	6.132	6.514	6.606	7.081
3.500	5.366	5.579	5.877	6.382	6.633	7.048	7.148	7.665
3.750	5.767	5.997	6.317	6.863	7.134	7.582	7.690	8.250
4.000	6.167	6.414	6.758	7.343	7.634	8.116	8.232	8.834
4.250	6.568	6.831	7.198	7.824	8.135	8.650	8.774	9.418
4.500	6.968	7.248	7.639	8.304	8.635	9.184	9.316	10.002
4.750	7.369	7.665	8.079	8.785	9.136	9.718	9.858	10.586
5.000	7.769	8.083	8.520	9.266	9.637	10.252	10.400	11.170
5.250	8.170	8.500	8.960	9.746	10.137	10.786	10.942	11.754
5.500	8.570	8.917	9.401	10.227	10.638	11.320	11.484	12.338
6.000	9.371	9.751	10.282	11.188	11.639	12.388	12.568	13.506
7.000	10.973	11.420	12.044	13.110	13.642	14.525	14.736	15.842
8.000	......	13.089	13.807	15.033	15.644	16.661	16.904	18.179
9.000	......	......	15.569	16.955	17.647	18.797	19.072	20.515
10.000	......	......	......	18.878	19.649	20.933	21.240	22.851
11.000	......	......	......	......	21.652	23.069	23.408	25.188
12.000	......	......	......	......	......	25.205	25.576	27.524
13.000	......	......	......	......	......	......	27.744	29.860
14.000	......	......	......	......	......	......	......	32.196
15.000	......	......	......	......	......	......	......	......
16.000	......	......	......	......	......	......	......	......
17.000	......	......	......	......	......	......	......	......
18.000	......	......	......	......	......	......	......	......
19.000	......	......	......	......	......	......	......	......
20.000	......	......	......	......	......	......	......	......
21.000	......	......	......	......	......	......	......	......
22.000	......	......	......	......	......	......	......	......
24.000	......	......	......	......	......	......	......	......
26.000	......	......	......	......	......	......	......	......
28.000	......	......	......	......	......	......	......	......
30.000	......	......	......	......	......	......	......	......

Weight per Foot of Tubes (or Outside Diameter Pipe) (Continued)

Outside diameter	Birmingham Wire Gage							
	5	4		3		2	1	
	Fractions and decimals of an inch							
	.220	.238	1/4 .250	.259	9/32 .28125	.284	.300	5/16 .3125
1.000	1.832	1.936	2.002	2.049	2.158	2.171	2.242	2.294
1.125	2.126	2.254	2.336	2.395	2.534	2.550	2.643	2.711
1.250	2.420	2.572	2.670	2.741	2.909	2.930	3.043	3.128
1.312	2.565	2.729	2.835	2.912	3.096	3.118	3.242	3.335
1.375	2.713	2.890	3.003	3.087	3.285	3.309	3.444	3.546
1.500	3.007	3.207	3.337	3.432	3.660	3.688	3.844	3.963
1.625	3.301	3.525	3.671	3.778	4.036	4.067	4.245	4.380
1.750	3.594	3.843	4.005	4.124	4.411	4.446	4.645	4.797
1.875	3.888	4.161	4.338	4.470	4.787	4.825	5.046	5.214
2.000	4.182	4.478	4.672	4.815	5.162	5.204	5.446	5.632
2.125	4.476	4.796	5.006	5.161	5.538	5.584	5.847	6.049
2.250	4.769	5.114	5.340	5.507	5.913	5.963	6.247	6.466
2.500	5.357	5.749	6.007	6.198	6.664	6.721	7.048	7.300
2.750	5.944	6.385	6.675	6.890	7.415	7.479	7.849	8.135
3.000	6.531	7.020	7.342	7.582	8.166	8.238	8.650	8.969
3.250	7.119	7.656	8.010	8.273	8.917	8.996	9.451	9.804
3.500	7.706	8.291	8.677	8.965	9.668	9.754	10.252	10.638
3.750	8.294	8.927	9.345	9.656	10.419	10.512	11.053	11.472
4.000	8.881	9.562	10.012	10.348	11.170	11.271	11.854	12.307
4.250	9.469	10.198	10.680	11.039	11.921	12.029	12.655	13.141
4.500	10.056	10.833	11.347	11.731	12.672	12.787	13.457	13.975
4.750	10.643	11.468	12.015	12.422	13.423	13.546	14.258	14.810
5.000	11.231	12.104	12.682	13.114	14.174	14.304	15.059	15.644
5.250	11.818	12.739	13.350	13.805	14.925	15.062	15.860	16.479
5.500	12.406	13.375	14.017	14.497	15.676	15.820	16.661	17.313
6.000	13.580	14.646	15.352	15.880	17.177	17.337	18.263	18.982
7.000	15.930	17.188	18.022	18.646	20.181	20.370	21.467	22.319
8.000	18.280	19.730	20.692	21.412	23.185	23.403	24.671	25.657
9.000	20.629	22.271	23.362	24.179	26.189	26.437	27.875	28.994
10.000	22.979	24.813	26.032	26.945	29.193	29.470	31.079	32.332
11.000	25.329	27.355	28.702	29.711	32.196	32.503	34.283	35.670
12.000	27.678	29.897	31.372	32.477	35.200	35.536	37.487	39.007
13.000	30.028	32.439	34.043	35.243	38.204	38.569	40.691	42.345
14.000	32.377	34.981	36.713	38.009	41.208	41.602	43.895	45.682
15.000	34.727	37.523	39.383	40.775	44.212	44.636	47.099	49.020
16.000	....	40.065	42.053	43.542	47.215	47.669	50.303	52.357
17.000	....	42.606	44.723	46.308	50.219	50.702	53.507	55.695
18.000	....	....	47.393	49.074	53.223	53.735	56.711	59.032
19.000	....	....	....	51.840	56.227	56.768	59.915	62.370
20.000	....	....	....	....	59.231	59.801	63.119	65.708
21.000	....	....	....	....	....	62.835	66.323	69.045
22.000	....	....	....	....	....	....	69.527	72.383
24.000	....	....	....	....	....	....	....	....
26.000	....	....	....	....	....	....	....	....
28.000	....	....	....	....	....	....	....	....
30.000	....	....	....	....	....	....	....	....

Weight per Foot of Tubes (or Outside Diameter Pipe) (Continued)

Outside diameter	Birmingham Wire Gage							
	0				00			000
	Fractions and decimals of an inch							
	.340	11/32 .34375	.350	3/8 .375	.380	.400	13/32 .40625	.425
1.000	2.396	2.409	2.429	2.503				
1.125	2.850	2.868	2.896	3.003				
1.250	3.304	3.327	3.364	3.504				
1.312	3.529	3.554	3.596	3.752	3.782			
1.375	3.758	3.786	3.831	4.005	4.038	4.165	4.203	
1.500	4.212	4.244	4.298	4.505	4.545	4.699	4.745	4.879
1.625	4.666	4.703	4.766	5.006	5.052	5.233	5.287	5.446
1.750	5.120	5.162	5.233	5.506	5.560	5.767	5.830	6.014
1.875	5.573	5.621	5.700	6.007	6.067	6.301	6.372	6.581
2.000	6.027	6.080	6.167	6.508	6.574	6.835	6.914	7.149
2.125	6.481	6.539	6.635	7.008	7.082	7.369	7.457	7.716
2.250	6.935	6.998	7.102	7.509	7.589	7.903	7.999	8.283
2.500	7.843	7.916	8.036	8.510	8.603	8.971	9.084	9.418
2.750	8.751	8.834	8.971	9.512	9.618	10.039	10.169	10.553
3.000	9.659	9.751	9.905	10.513	10.633	11.107	11.253	11.688
3.250	10.566	10.669	10.840	11.514	11.647	12.175	12.338	12.822
3.500	11.474	11.587	11.774	12.515	12.662	13.243	13.423	13.957
3.750	12.382	12.505	12.709	13.517	13.677	14.311	14.507	15.092
4.000	13.290	13.423	13.643	14.518	14.691	15.379	15.592	16.227
4.250	14.198	14.341	14.578	15.519	15.706	16.447	16.677	17.361
4.500	15.106	15.258	15.512	16.520	16.720	17.515	17.762	18.496
4.750	16.013	16.176	16.447	17.522	17.735	18.583	18.846	19.631
5.000	16.921	17.094	17.381	18.523	18.750	19.651	19.931	20.766
5.250	17.829	18.012	18.316	19.524	19.764	20.719	21.016	21.900
5.500	18.737	18.930	19.250	20.525	20.779	21.787	22.100	23.035
6.000	20.552	20.765	21.120	22.528	22.808	23.923	24.270	25.305
7.000	24.184	24.437	24.858	26.533	26.867	28.195	28.609	29.844
8.000	27.815	28.108	28.596	30.538	30.925	32.467	32.947	34.383
9.000	31.446	31.779	32.334	34.543	34.983	36.739	37.286	38.922
10.000	35.077	35.451	36.072	38.548	39.042	41.011	41.625	43.461
11.000	38.709	39.122	39.810	42.553	43.100	45.283	45.964	48.000
12.000	42.340	42.793	43.548	46.558	47.159	49.555	50.303	52.539
13.000	45.971	46.464	47.286	50.563	51.217	53.827	54.641	57.078
14.000	49.602	50.136	51.024	54.568	55.276	58.100	58.980	61.617
15.000	53.234	53.807	54.762	58.573	59.334	62.372	63.319	66.156
16.000	56.865	57.478	58.500	62.579	63.393	66.644	67.658	70.695
17.000	60.496	61.150	62.238	66.584	67.451	70.916	71.997	75.235
18.000	64.127	64.821	65.976	70.589	71.510	75.188	76.336	79.774
19.000	67.759	68.492	69.714	74.594	75.568	79.460	80.674	84.313
20.000	71.390	72.164	73.452	78.599	79.626	83.732	85.013	88.852
21.000	75.021	75.835	77.190	82.604	83.685	88.004	89.352	93.391
22.000	78.652	79.506	80.928	86.609	87.743	92.276	93.691	97.930
24.000	85.915	86.849	88.405	94.619	95.860	100.820	102.368	107.008
26.000	......	......	......	102.629	103.977	109.364	111.046	116.086
28.000	......	......	......	......	......	117.908	119.724	125.164
30.000	......	......	......	......	......	......	......	......

Weight per Foot of Tubes (or Outside Diameter Pipe) (Continued)

Outside diameter	Birmingham Wire Gage						
			0000				
	Fractions and decimals of an inch						
	7/16 .4375	.450	.454	15/32 .46875	1/2 .500	.550	9/16 .5625
1.000							
1.125							
1.250							
1.312							
1.375							
1.500	4.964	5.046	5.071	5.162	5.340	5.580	
1.625	5.548	5.647	5.677	5.788	6.007	6.314	
1.750	6.132	6.247	6.284	6.414	6.675	7.048	7.134
1.875	6.716	6.848	6.890	7.040	7.342	7.783	7.884
2.000	7.300	7.449	7.496	7.665	8.010	8.517	8.635
2.125	7.884	8.050	8.102	8.291	8.677	9.251	9.386
2.250	8.469	8.650	8.708	8.917	9.345	9.985	10.137
2.500	9.637	9.852	9.920	10.169	10.680	11.454	11.639
2.750	10.805	11.053	11.132	11.420	12.015	12.922	13.141
3.000	11.973	12.255	12.345	12.672	13.350	14.391	14.643
3.250	13.141	13.456	13.557	13.923	14.685	15.860	16.145
3.500	14.309	14.658	14.769	15.175	16.020	17.328	17.647
3.750	15.477	15.860	15.981	16.427	17.355	18.797	19.149
4.000	16.646	17.061	17.193	17.678	18.690	20.265	20.651
4.250	17.814	18.263	18.406	18.930	20.025	21.734	22.152
4.500	18.982	19.464	19.618	20.181	21.360	23.202	23.654
4.750	20.150	20.666	20.830	21.433	22.695	24.671	25.156
5.000	21.318	21.867	22.042	22.684	24.030	26.139	26.658
5.250	22.486	23.069	23.254	23.936	25.365	27.608	28.160
5.500	23.654	24.270	24.467	25.188	26.700	29.076	29.662
6.000	25.991	26.673	26.891	27.691	29.370	32.013	32.666
7.000	30.663	31.479	31.740	32.697	34.710	37.887	38.673
8.000	35.336	36.285	36.588	37.703	40.050	43.761	44.681
9.000	40.008	41.091	41.437	42.710	45.390	49.636	50.689
10.000	44.681	45.897	46.286	47.716	50.730	55.510	56.696
11.000	49.354	50.704	51.135	52.722	56.070	61.384	62.704
12.000	54.026	55.510	55.984	57.729	61.410	67.258	68.711
13.000	58.699	60.316	60.832	62.735	66.750	73.132	74.719
14.000	63.371	65.122	65.681	67.741	72.091	79.006	80.726
15.000	68.044	69.928	70.530	72.748	77.431	84.880	86.734
16.000	72.716	74.734	75.379	77.754	82.771	90.754	92.742
17.000	77.389	79.540	80.228	82.760	88.111	96.628	98.749
18.000	82.061	84.346	85.076	87.767	93.451	102.502	104.757
19.000	86.734	89.152	89.925	92.773	98.791	108.376	110.764
20.000	91.407	93.958	94.774	97.779	104.131	114.250	116.772
21.000	96.079	98.764	99.623	102.786	109.471	120.125	122.780
22.000	100.752	103.570	104.472	107.792	114.811	125.999	128.787
24.000	110.097	113.182	114.169	117.805	125.491	137.747	140.802
26.000	119.442	122.795	123.867	127.817	136.172	149.495	152.818
28.000	128.787	132.407	133.564	137.830	146.852	161.243	164.833
30.000	138.132	142.019	143.262	147.843	157.532	172.991	176.848

Weight per Foot of Tubes (or Outside Diameter Pipe) (Continued)

Outside diameter	Fractions and decimals of an inch						
	.600	5/8 .625	.650	11/16 .6875	.700	3/4 .750	.800
1.000							
1.125							
1.250							
1.312							
1.375							
1.500							
1.625							
1.750	7.369	7.509	7.636	7.801			
1.875	8.170	8.343	8.504	8.719			
2.000	8.971	9.178	9.371	9.637			
2.125	9.772	10.012	10.239	10.555			
2.250	10.573	10.847	11.107	11.472	11.587	12.015	12.388
2.500	12.175	12.515	12.842	13.308	13.457	14.017	14.525
2.750	13.777	14.184	14.578	15.144	15.326	16.020	16.661
3.000	15.379	15.853	16.313	16.979	17.195	18.022	18.797
3.250	16.981	17.522	18.049	18.815	19.064	20.025	20.933
3.500	18.583	19.190	19.784	20.651	20.933	22.027	23.069
3.750	20.185	20.859	21.520	22.486	22.802	24.030	25.205
4.000	21.787	22.528	23.256	24.322	24.671	26.032	27.341
4.250	23.389	24.197	24.991	26.158	26.540	28.035	29.477
4.500	24.991	25.866	26.727	27.993	28.409	30.037	31.613
4.750	26.593	27.534	28.462	29.829	30.278	32.040	33.749
5.000	28.195	29.203	30.198	31.665	32.147	34.043	35.885
5.250	29.797	30.872	31.933	33.500	34.016	36.045	38.021
5.500	31.399	32.541	33.669	35.336	35.885	38.048	40.157
6.000	34.603	35.878	37.140	39.007	39.623	42.053	44.429
7.000	41.011	42.553	44.082	46.350	47.099	50.063	52.973
8.000	47.419	49.228	51.024	53.692	54.575	58.073	61.517
9.000	53.827	55.903	57.966	61.035	62.051	66.083	70.061
10.000	60.236	62.579	64.908	68.378	69.527	74.093	78.605
11.000	66.644	69.254	71.850	75.720	77.003	82.103	87.150
12.000	73.052	75.929	78.792	83.063	84.480	90.113	95.694
13.000	79.460	82.604	85.734	90.405	91.956	98.123	104.238
14.000	85.868	89.279	92.677	97.748	99.432	106.134	112.782
15.000	92.276	95.954	99.619	105.091	106.908	114.144	121.326
16.000	98.684	102.629	106.561	112.433	114.384	122.154	129.870
17.000	105.092	109.304	113.503	119.776	121.860	130.164	138.414
18.000	111.500	115.979	120.445	127.118	129.336	138.174	146.958
19.000	117.908	122.654	127.387	134.461	136.812	146.184	155.503
20.000	124.317	129.330	134.329	141.804	144.288	154.194	164.047
21.000	130.725	136.005	141.271	149.146	151.765	162.204	172.591
22.000	137.133	142.680	148.213	156.489	159.241	170.215	181.135
24.000	149.949	156.030	162.098	171.174	174.193	186.235	198.223
26.000	162.765	169.380	175.982	185.859	189.145	202.255	215.312
28.000	175.581	182.730	189.866	200.545	204.097	218.275	
30.000	188.397	196.081	203.750	215.230	219.050	234.296	

Weight per Foot of Tubes (or Outside Diameter Pipe) (Concluded)

Outside diameter	Fractions and decimals of an inch						
	13/16 .8125	.850	7/8 .875	.900	15/16 .9375	1	1 1/8 1.125
1.000							
1.125							
1.250							
1.312							
1.375							
1.500							
1.625							
1.750							
1.875							
2.000							
2.125							
2.250	12.474	12.709	12.849				
2.500	14.643	14.978	15.185				
2.750	16.812	17.248	17.522				
3.000	18.982	19.517	19.858	20.185	20.651	21.360	
3.250	21.151	21.787	22.194	22.588	23.154	24.030	
3.500	23.321	24.057	24.530	24.991	25.657	26.700	
3.750	25.490	26.326	26.867	27.394	28.160	29.370	
4.000	27.659	28.596	29.203	29.797	30.663	32.040	
4.250	29.829	30.865	31.539	32.200	33.166	34.710	
4.500	31.998	33.135	33.876	34.603	35.670	37.380	
4.750	34.168	35.404	36.212	37.006	38.173	40.050	
5.000	36.337	37.674	38.548	39.409	40.676	42.720	
5.250	38.506	39.943	40.884	41.812	43.179	45.390	
5.500	40.676	42.213	43.221	44.215	45.682	48.060	
6.000	45.015	46.752	47.893	49.021	50.689	53.400	
7.000	53.692	55.830	57.238	58.634	60.701	64.080	
8.000	62.370	64.908	66.584	68.246	70.714	74.761	
9.000	71.048	73.986	75.929	77.858	80.726	85.441	
10.000	79.725	83.064	85.274	87.470	90.739	96.121	
11.000	88.403	92.143	94.619	97.082	100.752	106.801	
12.000	97.080	101.221	103.964	106.694	110.764	117.481	
13.000	105.758	110.299	113.309	116.306	120.777	128.161	142.680
14.000	114.436	119.377	122.654	125.919	130.790	138.842	154.695
15.000	123.113	128.455	132.000	135.531	140.802	149.522	166.710
16.000	131.791	137.533	141.345	145.143	150.815	160.202	178.725
17.000	140.469	146.611	150.690	154.755	160.828	170.882	190.740
18.000	149.146	155.690	160.035	164.367	170.840	181.562	202.756
19.000	157.824	164.768	169.380	173.979	180.853	192.242	214.771
20.000	166.502	173.846	178.725	183.591	190.866	202.923	226.786
21.000	175.179	182.924					
22.000	183.857	192.002					
24.000	201.212	210.158					
26.000	218.567	228.315					
28.000							
30.000							

Length of Pipe for One Square Foot of Surface

Size	External diameter	Standard weight pipe			Extra strong pipe			Double extra strong pipe		
		Thickness	Length of pipe in ft. per sq. ft. of		Thickness	Length of pipe in ft. per sq. ft. of		Thickness	Length of pipe in ft. per sq. ft. of	
			External surface	Internal surface		External surface	Internal surface		External surface	Internal surface
1/8	.405	.068	9.431	14.199	.095	9.431	17.766	......	......	......
1/4	.540	.088	7.073	10.493	.119	7.073	12.648	......	......	......
3/8	.675	.091	5.658	7.747	.126	5.658	9.030	......	......	......
1/2	.840	.109	4.547	6.141	.147	4.547	6.995	.294	4.547	15.157
3/4	1.050	.113	3.637	4.635	.154	3.637	5.147	.308	3.637	8.801
1	1.315	.133	2.904	3.641	.179	2.904	3.991	.358	2.904	6.376
1 1/4	1.660	.140	2.301	2.767	.191	2.301	2.988	.382	2.301	4.263
1 1/2	1.900	.145	2.010	2.372	.200	2.010	2.546	.400	2.010	3.472
2	2.375	.154	1.608	1.847	.218	1.608	1.969	.436	1.608	2.541
2 1/2	2.875	.203	1.328	1.547	.276	1.328	1.644	.552	1.328	2.156
3	3.500	.216	1.091	1.245	.300	1.091	1.317	.600	1.091	1.660
3 1/2	4.000	.226	.954	1.076	.318	.954	1.135	.636	.954	1.400
4	4.500	.237	.848	.948	.337	.848	.998	.674	.848	1.211
4 1/2	5.000	.247	.763	.847	.355	.763	.890	.710	.763	1.066
5	5.563	.258	.686	.756	.375	.686	.793	.750	.686	.940
6	6.625	.280	.576	.629	.432	.576	.663	.864	.576	.780
7	7.625	.301	.500	.543	.500	.500	.576	.875	.500	.650
8	8.625	.277	.442	.473	.500	.442	.500	.875	.442	.555
8	8.625	.322	.442	.478	......	......	......	......	......	......
9	9.625	.342	.396	.427	.500	.396	.442	......	......	......
10	10.750	.279	.355	.374	.500	.355	.391	......	......	......
10	10.750	.307	.355	.376	......	......	......	......	......	......
10	10.750	.365	.355	.381	......	......	......	......	......	......
11	11.750	.375	.325	.347	.500	.325	.355	......	......	......
12	12.750	.330	.299	.315	.500	.299	.325	......	......	......
12	12.750	.375	.299	.318	......	......	......	......	......	......
13	14.000	.375	.272	.288	.500	.272	.293	......	......	......
14	15.000	.375	.254	.268	.500	.254	.272	......	......	......
15	16.000	.375	.238	.250	.500	.238	.254	......	......	......

Properties of Pipe

$$\text{Strength factor } Q = \frac{\text{foot pounds}}{1000} = \frac{I}{y} \times \frac{27\,000}{1\,000} \times \frac{1}{12} = \frac{9}{2}\frac{I}{\text{O. D.}},$$

y = distance of farthest fiber from axis.

External diameter O. D.	Thickness	Weight per foot	Moment of inertia I	Section modulus I/y	Area of metal, square inches A	Radius of gyration squared $R^2=I/A$	Radius of gyration R	Strength factor Q
.375	.065	.215	.0007939	.004234	.06330	.01254	.1120	.009526
.405	.068	.244	.001064	.005252	.07199	.01477	.1215	.01182
.405	.095	.314	.001216	.006004	.09252	.01314	.1146	.01351
.500	.065	.301	.002148	.008592	.08883	.02418	.1555	.01933
.540	.088	.424	.003312	.01227	.1250	.02651	.1628	.02760
.540	.119	.535	.003766	.01395	.1574	.02393	.1547	.03138
.625	.069	.409	.004729	.01513	.1205	.03924	.1981	.03405
.675	.091	.567	.007291	.02160	.1670	.04367	.2090	.04860
.675	.126	.738	.008619	.02554	.2173	.03966	.1991	.05746
.750	.078	.559	.009421	.02512	.1647	.05721	.2392	.05652
.840	.078	.634	.01369	.03261	.1867	.07334	.2708	.07336
.840	.109	.850	.01709	.04069	.2503	.06828	.2613	.09156
.840	.147	1.087	.02008	.04780	.3200	.06273	.2505	.1076
.840	.294	1.714	.02424	.05772	.5043	.04807	.2192	.1299
.875	.078	.663	.01566	.03578	.1953	.08016	.2831	.08051
1.000	.078	.768	.02418	.04836	.2259	.1070	.3271	.1088
1.050	.078	.809	.02831	.05392	.2382	.1189	.3448	.1213
1.050	.113	1.130	.03704	.07055	.3326	.1113	.3337	.1587
1.050	.154	1.473	.04479	.08531	.4335	.1033	.3214	.1919
1.050	.308	2.440	.05792	.1103	.7180	.08068	.2840	.2482
1.250	.089	1.103	.05502	.08803	.3246	.1695	.4117	.1981
1.315	.089	1.165	.06474	.09847	.3428	.1889	.4346	.2216
1.315	.133	1.678	.08734	.1328	.4939	.1769	.4205	.2989
1.315	.179	2.171	.1056	.1606	.6388	.1653	.4066	.3614
1.315	.358	3.659	.1405	.2136	1.076	.1305	.3613	.4807
1.500	.095	1.425	.1039	.1386	.4193	.2479	.4979	.3118
1.500	.109	1.619	.1159	.1545	.4763	.2433	.4933	.3477
1.500	.110	1.632	.1167	.1556	.4803	.2430	.4930	.3502
1.500	.120	1.768	.1248	.1664	.5202	.2398	.4897	.3743
1.500	.125	1.835	.1287	.1716	.5400	.2383	.4881	.3860
1.500	.134	1.954	.1354	.1806	.5750	.2355	.4853	.4063
1.500	.135	1.968	.1362	.1815	.5789	.2352	.4850	.4085
1.500	.148	2.137	.1454	.1938	.6286	.2312	.4809	.4361
1.500	.150	2.162	.1467	.1956	.6362	.2306	.4802	.4402
1.660	.095	1.587	.1435	.1729	.4671	.3073	.5543	.3891
1.660	.140	2.272	.1947	.2346	.6685	.2913	.5397	.5278
1.660	.191	2.996	.2418	.2913	.8815	.2743	.5237	.6555
1.660	.382	5.214	.3411	.4110	1.534	.2224	.4716	.9247
1.750	.095	1.679	.1697	.1939	.4939	.3435	.5861	.4363
1.750	.109	1.910	.1900	.2171	.5619	.3381	.5815	.4885

Properties of Pipe (Continued)

$$\text{Strength factor } Q = \frac{\text{foot pounds}}{1000} = \frac{I}{y} \times \frac{27\,000}{1\,000} \times \frac{1}{12} = \frac{9}{2}\frac{I}{\text{O. D.}},$$

y = distance of farthest fiber from axis.

External diameter O. D.	Thickness	Weight per foot	Moment of inertia I	Section modulus I/y	Area of metal, square inches A	Radius of gyration squared $R^2=I/A$	Radius of gyration R	Strength factor Q
1.750	.110	1.926	.1914	.2187	.5667	.3377	.5811	.4922
1.750	.120	2.089	.2052	.2345	.6145	.3339	.5779	.5276
1.750	.125	2.169	.2119	.2422	.6381	.3320	.5762	.5448
1.750	.134	2.312	.2236	.2555	.6803	.3287	.5733	.5750
1.750	.135	2.328	.2249	.2570	.6849	.3283	.5730	.5782
1.750	.148	2.532	.2410	.2754	.7449	.3235	.5688	.6197
1.750	.150	2.563	.2434	.2782	.7540	.3228	.5682	.6259
1.875	.095	1.806	.2110	.2251	.5312	.3972	.6302	.5064
1.875	.109	2.055	.2367	.2524	.6047	.3913	.6256	.5680
1.875	.110	2.073	.2384	.2543	.6099	.3909	.6252	.5722
1.875	.120	2.249	.2559	.2730	.6616	.3868	.6219	.6142
1.875	.125	2.336	.2644	.2820	.6872	.3848	.6203	.6346
1.875	.134	2.491	.2793	.2980	.7329	.3811	.6174	.6704
1.875	.135	2.508	.2810	.2997	.7380	.3807	.6170	.6743
1.875	.148	2.729	.3016	.3217	.8030	.3756	.6128	.7237
1.875	.150	2.763	.3046	.3250	.8129	.3748	.6122	.7311
1.900	.109	2.084	.2468	.2598	.6133	.4024	.6344	.5846
1.900	.145	2.717	.3099	.3262	.7995	.3876	.6226	.7340
1.900	.159	2.956	.3322	.3497	.8697	.3820	.6181	.7869
1.900	.200	3.631	.3912	.4118	1.068	.3663	.6052	.9265
1.900	.400	6.408	.5678	.5977	1.885	.3013	.5489	1.345
2.000	.095	1 932	.2586	.2586	.5685	.4548	.6744	.5817
2.000	.109	2.201	.2904	.2904	.6475	.4485	.6697	.6534
2.000	.110	2.220	.2926	.2926	.6531	.4480	.6693	.6584
2.000	.120	2.409	.3144	.3144	.7087	.4436	.6660	.7074
2.000	.125	2.503	.3250	.3250	.7363	.4414	.6644	.7313
2.000	.134	2.670	.3437	.3437	.7855	.4375	.6614	.7732
2.000	.135	2.688	.3457	.3457	.7910	.4371	.6611	.7778
2.000	.148	2.927	.3715	.3715	.8611	.4315	.6569	.8360
2.000	.150	2.963	.3754	.3754	.8718	.4306	.6562	.8447
2.250	.095	2.186	.3741	.3325	.6432	.5816	.7626	.7482
2.250	.100	2.296	.3911	.3477	.6754	.5791	.7610	.7822
2.250	.109	2.492	.4212	.3744	.7332	.5745	.7579	.8423
2.250	.110	2.514	.4245	.3773	.7395	.5740	.7576	.8489
2.250	.120	2.729	.4568	.4061	.8030	.5689	.7543	.9137
2.250	.125	2.836	.4727	.4201	.8345	.5664	.7526	.9453
2.250	.134	3.028	.5006	.4449	.8908	.5619	.7496	1.001
2.250	.135	3.049	.5036	.4476	.8970	.5614	.7493	1.007
2.250	.148	3.322	.5425	.4822	.9773	.5550	.7450	1.085
2.250	.150	3.364	.5483	.4874	.9896	.5541	.7444	1.097

Properties of Pipe (Continued)

$$\text{Strength factor } Q = \frac{\text{foot pounds}}{1000} = \frac{I}{y} \times \frac{27\,000}{1\,000} \times \frac{1}{12} = \frac{9}{2} \frac{I}{\text{O. D.}},$$

y = distance of farthest fiber from axis.

External diameter O. D.	Thickness	Weight per foot	Moment of inertia I	Section modulus I/y	Area of metal, square inches A	Radius of gyration squared $R^2=I/A$	Radius of gyration R	Strength factor Q
2.375	.130	3.117	.5796	.4881	.9169	.6321	.7951	1.098
2.375	.134	3.207	.5943	.5005	.9434	.6300	.7937	1.126
2.375	.154	3.652	.6657	.5606	1.075	.6196	.7871	1.261
2.375	.166	3.916	.7066	.5951	1.152	.6134	.7832	1.339
2.375	.167	3.938	.7100	.5979	1.158	.6129	.7829	1.345
2.375	.187	4.380	.7748	.6525	1.285	.6028	.7764	1.468
2.375	.190	4.433	.7842	.6604	1.304	.6013	.7754	1.486
2.375	.218	5.022	.8679	.7309	1.477	.5875	.7665	1.644
2.375	.436	9.029	1.311	1.104	2.656	.4937	.7027	2.485
2.500	.095	2.440	.5198	.4158	.7178	.7241	.8510	.9356
2.500	.108	2.759	.5816	.4653	.8116	.7167	.8466	1.047
2.500	.109	2.783	.5863	.4690	.8188	.7161	.8462	1.055
2.500	.110	2.807	.5910	.4728	.8259	.7155	.8459	1.064
2.500	.120	3.050	.6369	.5095	.8972	.7098	.8425	1.146
2.500	.125	3.170	.6594	.5275	.9327	.7070	.8409	1.187
2.500	.134	3.386	.6992	.5594	.9960	.7020	.8378	1.259
2.500	.135	3.409	.7036	.5628	1.003	.7014	.8375	1.266
2.500	.148	3.717	.7592	.6074	1.094	.6942	.8332	1.367
2.500	.150	3.764	.7676	.6141	1.107	.6931	.8325	1.382
2.750	.109	3.074	.7898	.5744	.9044	.8733	.9345	1.292
2.750	.113	3.182	.8152	.5929	.9361	.8708	.9332	1.334
2.875	.183	5.261	1.408	.9798	1.548	.9100	.9540	2.205
2.875	.203	5.793	1.530	1.064	1.704	.8976	.9474	2.394
2.875	.217	6.160	1.611	1.121	1.812	.8890	.9429	2.521
2.875	.226	6.393	1.662	1.156	1.881	.8835	.9400	2.601
2.875	.276	7.661	1.924	1.339	2.254	.8539	.9241	3.012
2.875	.552	13.695	2.871	1.997	4.028	.7126	.8442	4.493
3.000	.095	2.947	.9156	.6104	.8670	1.056	1.028	1.373
3.000	.109	3.365	1.036	.6905	.9900	1.046	1.023	1.554
3.000	.110	3.395	1.044	.6961	.9987	1.046	1.023	1.566
3.000	.116	3.572	1.094	.7297	1.051	1.041	1.020	1.642
3.000	.120	3.691	1.128	.7518	1.086	1.039	1.019	1.691
3.000	.125	3.838	1.169	.7791	1.129	1.035	1.017	1.753
3.000	.134	4.101	1.241	.8277	1.207	1.029	1.014	1.862
3.000	.135	4.130	1.249	.8330	1.215	1.028	1.014	1.874
3.000	.148	4.508	1.352	.9013	1.326	1.019	1.010	2.028
3.000	.150	4.565	1.367	.9116	1.343	1.018	1.009	2.051
3.000	.165	4.995	1.481	.9876	1.470	1.008	1.004	2.222
3.250	.120	4.011	1.447	.8906	1.180	1.226	1.107	2.004
3.500	.120	4.331	1.822	1.041	1.274	1.430	1.196	2.343

Properties of Pipe (Continued)

$$\text{Strength factor } Q = \frac{\text{foot pounds}}{1000} = \frac{I}{y} \times \frac{27\,000}{1\,000} \times \frac{1}{12} = \frac{9}{2}\,\frac{I}{\text{O. D.}}$$

y = distance of farthest fiber from axis.

External diameter O. D.	Thickness	Weight per foot	Moment of inertia I	Section modulus I/y	Area of metal, square inches A	Radius of gyration squared $R^2=I/A$	Radius of gyration R	Strength factor Q
3.500	.125	4.505	1.890	1.080	1.325	1.426	1.194	2.430
3.500	.216	7.575	3.017	1.724	2.228	1.354	1.164	3.879
3.500	.218	7.641	3.040	1.737	2.248	1.352	1.163	3.908
3.500	.241	8.388	3.294	1.882	2.467	1.335	1.155	4.235
3.500	.255	8.837	3.443	1.967	2.600	1.324	1.151	4.427
3.500	.289	9.910	3.788	2.164	2.915	1.299	1.140	4.870
3.500	.300	10.252	3.894	2.225	3.016	1.291	1.136	5.007
3.500	.600	18.583	5.993	3.424	5.466	1.096	1.047	7.705
3.750	.120	4.652	2.257	1.203	1.368	1.649	1.284	2.708
3.750	.129	4.988	2.408	1.284	1.467	1.641	1.281	2.890
4.000	.128	5.293	2.921	1.461	1.557	1.876	1.370	3.286
4.000	.134	5.532	3.044	1.522	1.627	1.870	1.368	3.425
4.000	.226	9.109	4.788	2.394	2.680	1.787	1.337	5.386
4.000	.250	10.012	5.200	2.600	2.945	1.766	1.329	5.850
4.000	.318	12.505	6.280	3.140	3.678	1.707	1.307	7.065
4.000	.636	22.850	9.848	4.924	6.721	1.465	1.210	11.08
4.250	.138	6.060	3.772	1.775	1.783	2.116	1.455	3.994
4.500	.134	6.248	4.384	1.948	1.838	2.385	1.544	4.384
4.500	.142	6.609	4.620	2.053	1.944	2.377	1.542	4.620
4.500	.205	9.403	6.393	2.841	2.766	2.311	1.520	6.393
4.500	.237	10.790	7.233	3.214	3.174	2.279	1.510	7.233
4.500	.250	11.347	7.563	3.361	3.338	2.266	1.505	7.563
4.500	.252	11.433	7.613	3.383	3.363	2.264	1.505	7.613
4.500	.255	11.561	7.688	3.417	3.401	2.261	1.504	7.688
4.500	.271	12.240	8.082	3.592	3.600	2.245	1.498	8.082
4.500	.337	14.983	9.610	4.271	4.407	2.181	1.477	9.610
4.500	.674	27.541	15.28	6.793	8.101	1.887	1.374	15.28
4.750	.145	7.131	5.566	2.344	2.098	2.653	1.629	5.273
4.750	.193	9.393	7.185	3.025	2.763	2.600	1.613	6.807
4.750	.334	15.752	11.36	4.783	4.634	2.452	1.566	10.76
5.000	.134	6.963	6.068	2.427	2.048	2.962	1.721	5.461
5.000	.148	7.669	6.645	2.658	2.256	2.945	1.716	5.980
5.000	.152	7.870	6.808	2.723	2.315	2.941	1.715	6.127
5.000	.247	12.538	10.44	4.177	3.688	2.832	1.683	9.399
5.000	.250	12.682	10.55	4.220	3.731	2.828	1.682	9.496
5.000	.288	14.493	11.88	4.751	4.263	2.786	1.669	10.69
5.000	.306	15.340	12.48	4.992	4.512	2.766	1.663	11.23
5.000	.355	17.611	14.05	5.621	5.180	2.712	1.647	12.65
5.000	.710	32.530	22.62	9.047	9.569	2.364	1.537	20.35
5.250	.153	8.328	7.963	3.034	2.450	3.250	1.803	6.826

Properties of Pipe (Continued)

$$\text{Strength factor } Q = \frac{\text{foot pounds}}{1000} = \frac{I}{y} \times \frac{27\,000}{1\,000} \times \frac{1}{12} = \frac{9}{2}\frac{I}{\text{O. D.}},$$

y = distance of farthest fiber from axis.

External diameter O. D.	Thickness	Weight per foot	Moment of inertia I	Section modulus I/y	Area of metal, square inches A	Radius of gyration squared $R^2=I/A$	Radius of gyration R	Strength factor Q
5.250	.182	9.851	9.315	3.549	2.898	3.215	1.793	7.985
5.250	.241	12.892	11.92	4.542	3.792	3.144	1.773	10.22
5.250	.301	15.909	14.38	5.478	4.680	3.073	1.753	12.33
5.500	.154	8.792	9.248	3.363	2.586	3.575	1.891	7.566
5.500	.228	12.837	13.14	4.780	3.776	3.481	1.866	10.75
5.500	.304	16.870	16.80	6.111	4.962	3.386	1.840	13.75
5.563	.258	14.617	15.16	5.451	4.300	3.526	1.878	12.26
5.563	.293	16.491	16.89	6.073	4.851	3.482	1.866	13.66
5.563	.304	17.074	17.42	6.263	5.023	3.469	1.862	14.09
5.563	.375	20.778	20.67	7.431	6.112	3.382	1.839	16.72
5.563	.750	38.552	33.63	12.09	11.34	2.966	1.722	27.21
6.000	.140	8.762	11.07	3.690	2.577	4.295	2.072	8.302
6.000	.164	10.222	12.81	4.270	3.007	4.261	2.064	9.608
6.000	.165	10.282	12.88	4.294	3.025	4.259	2.064	9.662
6.000	.190	11.789	14.65	4.883	3.468	4.224	2.055	10.99
6.000	.224	13.818	16.98	5.659	4.065	4.177	2.044	12.73
6.000	.275	16.814	20.31	6.770	4.946	4.106	2.026	15.23
6.000	.280	17.105	20.63	6.876	5.032	4.100	2.025	15.47
6.000	.324	19.641	23.34	7.781	5.777	4.040	2.010	17.51
6.625	.169	11.652	17.87	5.395	3.428	5.214	2.283	12.14
6.625	.184	12.657	19.32	5.834	3.723	5.190	2.278	13.13
6.625	.185	12.724	19.42	5.863	3.743	5.188	2.278	13.19
6.625	.245	16.694	25.02	7.554	4.911	5.096	2.257	17.00
6.625	.280	18.974	28.14	8.496	5.581	5.042	2.245	19.12
6.625	.281	19.039	28.23	8.522	5.600	5.041	2.245	19.17
6.625	.288	19.491	28.84	8.707	5.734	5.030	2.243	19.59
6.625	.300	20.265	29.88	9.020	5.961	5.012	2.239	20.29
6.625	.344	23.076	33.57	10.14	6.788	4.946	2.224	22.80
6.625	.385	25.658	36.87	11.13	7.547	4.886	2.210	25.05
6.625	.417	27.648	39.36	11.88	8.133	4.839	2.200	26.73
6.625	.432	28.573	40.49	12.22	8.405	4.817	2.195	27.50
6.625	.864	53.160	66.33	20.02	15.64	4.242	2.060	45.06
7.000	.149	10.902	18.82	5.378	3.207	5.870	2.423	12.10
7.000	.165	12.044	20.70	5.915	3.543	5.843	2.417	13.31
7.000	.174	12.685	21.75	6.213	3.731	5.828	2.414	13.98
7.000	.231	16.699	28.17	8.048	4.912	5.734	2.395	18.11
7.000	.272	19.544	32.58	9.310	5.749	5.667	2.381	20.95
7.000	.275	19.751	32.90	9.400	5.810	5.662	2.380	21.15
7.000	.301	21.535	35.61	10.17	6.335	5.621	2.371	22.89
7.000	.333	23.711	38.85	11.10	6.975	5.570	2.360	24.97

Properties of Pipe (Continued)

$$\text{Strength factor } Q = \frac{\text{foot pounds}}{1000} = \frac{I}{y} \times \frac{27\,000}{1\,000} \times \frac{1}{12} = \frac{9}{2}\,\frac{I}{\text{O. D.}},$$

y = distance of farthest fiber from axis.

External diameter O. D.	Thickness	Weight per foot	Moment of inertia I	Section modulus I/y	Area of metal, square inches A	Radius of gyration squared $R^2 = I/A$	Radius of gyration R	Strength factor Q
7.000	.362	25.663	41.70	11.92	7.549	5.524	2.350	26.81
7.000	.393	27.731	44.67	12.76	8.157	5.476	2.340	28.72
7.625	.181	14.390	29.34	7.695	4.233	6.931	2.633	17.31
7.625	.301	23.544	46.52	12.20	6.926	6.716	2.592	27.45
7.625	.500	38.048	71.37	18.72	11.19	6.377	2.525	42.12
7.625	.875	63.079	107.5	28.18	18.56	5.791	2.406	63.41
8.000	.158	13.233	29.93	7.484	3.893	7.690	2.773	16.84
8.000	.165	13.807	31.18	7.795	4.061	7.677	2.771	17.54
8.000	.185	15.441	34.69	8.674	4.542	7.639	2.764	19.52
8.000	.186	15.522	34.87	8.717	4.566	7.637	2.763	19.61
8.000	.236	19.569	43.41	10.85	5.756	7.542	2.746	24.42
8.000	.307	25.223	54.98	13.74	7.420	7.410	2.722	30.92
8.000	.322	26.404	57.34	14.33	7.767	7.382	2.717	32.25
8.625	.188	16.940	44.36	10.29	4.983	8.902	2.984	23.14
8.625	.217	19.486	50.69	11.75	5.732	8.843	2.974	26.44
8.625	.264	23.574	60.66	14.07	6.934	8.747	2.958	31.65
8.625	.277	24.696	63.35	14.69	7.265	8.721	2.953	33.05
8.625	.304	27.016	68.87	15.97	7.947	8.666	2.944	35.93
8.625	.311	27.615	70.28	16.30	8.123	8.652	2.941	36.67
8.625	.322	28.554	72.49	16.81	8.399	8.630	2.938	37.82
8.625	.352	31.101	78.41	18.18	9.149	8.571	2.928	40.91
8.625	.354	31.270	78.80	18.27	9.198	8.567	2.927	41.11
8.625	.400	35.137	87.61	20.32	10.34	8.476	2.911	45.71
8.625	.425	37.220	92.27	21.40	10.95	8.428	2.903	48.14
8.625	.487	42.327	103.4	23.99	12.45	8.308	2.882	53.97
8.625	.500	43.388	105.7	24 51	12.76	8.283	2.878	55.16
8.625	.875	72.424	162.0	37.56	21.30	7.604	2.757	84.51
9.000	.167	15.754	45.21	10.05	4.634	9.756	3.123	22.61
9.000	.180	16.955	48.52	10.78	4.988	9.728	3.119	24.26
9.000	.196	18.429	52.55	11.68	5.421	9.694	3.113	26.27
9.000	.250	23.362	65.82	14.63	6.872	9.578	3.095	32.91
9.000	.342	31.624	87.30	19.40	9.302	9.385	3.063	43.65
9.625	.342	33.907	107.6	22.35	9.974	10.79	3.284	50.30
9.625	.500	48.728	149.6	31.09	14.33	10.44	3.231	69.96
10.000	.175	18.363	65.20	13.04	5.402	12.07	3.474	29.34
10.000	.203	21.240	74.99	15.00	6.248	12.00	3.465	33.75
10.000	.208	21.752	76.72	15.34	6.399	11.99	3.463	34.53
10.000	.209	21.855	77.07	15.41	6.429	11.99	3.462	34.68
10.000	.270	28.057	97.75	19.55	8.253	11.84	3.441	43.99
10.000	.283	29.369	102.0	20.41	8.639	11.81	3.437	45.92

Properties of Pipe (Continued)

$$\text{Strength factor } Q = \frac{\text{foot pounds}}{1000} = \frac{I}{y} \times \frac{27\ 000}{1\ 000} \times \frac{1}{12} = \frac{9}{2} \frac{I}{\text{O. D.}}.$$

y = distance of farthest fiber from axis.

External diameter O.D.	Thickness	Weight per foot	Moment of inertia I	Section modulus I/y	Area of metal, square inches A	Radius of gyration squared $R^2=I/A$	Radius of gyration R	Strength factor Q
10.000	.308	31.881	110.2	22.05	9.378	11.75	3.428	49.60
10.000	.365	37.559	128.4	25.68	11.05	11.62	3.409	57.78
10.750	.279	31.201	125.9	23.42	9.178	13.71	3.703	52.69
10.750	.302	33.699	135.4	25.19	9.913	13.66	3.695	56.67
10.750	.307	34.240	137.4	25.57	10.07	13.64	3.694	57.52
10.750	.348	38.661	154.0	28.65	11.37	13.54	3.680	64.46
10.750	.365	40.483	160.7	29.90	11.91	13.50	3.674	67.28
10.750	.395	43.684	172.5	32.09	12.85	13.42	3.664	72.20
10.750	.424	46.760	183.6	34.16	13.75	13.35	3.654	76.87
10.750	.483	52.962	205.7	38.28	15.58	13.21	3.634	86.12
10.750	.500	54.735	212.0	39.43	16.10	13.16	3.628	88.72
11.000	.185	21.368	91.93	16.71	6.286	14.62	3.824	37.61
11.000	.220	25.329	108.3	19.69	7.451	14.53	3.812	44.29
11.000	.224	25.780	110.1	20.02	7.583	14.52	3.811	45.05
11.000	.290	33.171	140.0	25.46	9.757	14.35	3.788	57.27
11.750	.375	45.557	217.0	36.93	13.40	16.19	4.024	83.10
11.750	.500	60.075	280.1	47.68	17.67	15.85	3.981	107.3
12.000	.194	24.461	125.4	20.90	7.195	17.43	4.175	47.02
12.000	.229	28.788	146.7	24.45	8.468	17.33	4.162	55.02
12.000	.243	30.512	155.1	25.86	8.975	17.29	4.158	58.18
12.000	.244	30.635	155.7	25.96	9.012	17.28	4.157	58.40
12.000	.308	38.460	193.5	32.24	11.31	17.10	4.135	72.55
12.000	.310	38.703	194.6	32.44	11.38	17.09	4.134	72.98
12.000	.375	46.558	231.6	38.60	13.70	16.91	4.112	86.85
12.750	.330	43.773	248.5	38.97	12.88	19.30	4.393	87.69
12.750	.375	49.562	279.3	43.82	14.58	19.16	4.377	98.59
12.750	.500	65.415	361.5	56.71	19.24	18.79	4.335	127.6
13.000	.202	27.610	166.3	25.59	8.122	20.48	4.525	57.57
13.000	.238	32.439	194.3	29.90	9.542	20.37	4.513	67.27
13.000	.247	33.642	201.3	30.96	9.896	20.34	4.510	69.67
13.000	.259	35.243	210.5	32.38	10.37	20.30	4.506	72.85
13.000	.281	38.171	227.2	34.95	11.23	20.23	4.498	78.63
13.000	.310	42.014	248.9	38.30	12.36	20.14	4.488	86.17
13.000	.320	43.335	256.4	39.44	12.75	20.11	4.484	88.74
13.000	.359	48.467	285.0	43.85	14.26	19.99	4.471	98.65
13.000	.361	48.730	286.5	44.07	14.33	19.98	4.470	99.16
14.000	.210	30.928	216.3	30.90	9.098	23.78	4.876	69.53
14.000	.248	36.424	253.4	36.20	10.71	23.65	4.863	81.46
14.000	.250	36.713	255.3	36.47	10.80	23.64	4.862	82.06
14.000	.276	40.454	280.3	40.04	11.90	23.55	4.853	90.09

Properties of Pipe (Concluded)

$$\text{Strength factor } Q = \frac{\text{foot pounds}}{1000} = \frac{I}{y} \times \frac{27\,000}{1\,000} \times \frac{1}{12} = \frac{9}{2}\frac{I}{\text{O. D.}},$$

y = distance of farthest fiber from axis.

External diameter O.D.	Thickness	Weight per foot	Moment of inertia I	Section modulus I/y	Area of metal, square inches A	Radius of gyration squared $R^2 = I/A$	Radius of gyration R	Strength factor Q
14.000	.310	45.325	312.5	44.64	13.33	23.44	4.841	100.4
14.000	.328	47.894	329.4	47.05	14.09	23.38	4.835	105.9
14.000	.375	54.568	372.8	53.25	16.05	23.22	4.819	119.8
14.000	.438	63.441	429.5	61.36	18.66	23.01	4.797	138.1
14.000	.500	72.091	483.8	69.11	21.21	22.81	4.776	155.5
15.000	.222	35.038	281.4	37.52	10.31	27.30	5.225	84.43
15.000	.259	40.775	325.9	43.45	11.99	27.17	5.213	97.77
15.000	.260	40.930	327.1	43.61	12.04	27.17	5.212	98.13
15.000	.291	45.714	363.8	48.51	13.45	27.05	5.201	109.1
15.000	.320	50.171	397.7	53.03	14.76	26.95	5.191	119.3
15.000	.375	58.573	461.0	61.46	17.23	26.75	5.172	138.3
15.000	.438	68.119	531.6	70.88	20.04	26.53	5.151	159.5
15.000	.500	77.431	599.3	79.91	22.78	26.31	5.130	179.8
16.000	.234	39.401	360.2	45.02	11.59	31.08	5.575	101.3
16.000	.270	45.359	412.8	51.60	13.34	30.94	5.562	116.1
16.000	.302	50.632	458.9	57.37	14.89	30.81	5.551	129.1
16.000	.330	55.228	498.9	62.36	16.25	30.71	5.541	140.3
16.000	.375	62.579	562.1	70.26	18.41	30.54	5.526	158.1
16.000	.401	66.806	598.1	74.76	19.65	30.44	5.517	168.2
16.000	.500	82.771	731.9	91.49	24.35	30.06	5.483	205.9
17.000	.240	42.959	443.8	52.21	12.64	35.12	5.926	117.5
17.000	.393	69.704	707.2	83.21	20.50	34.49	5.873	187.2
18.000	.245	46.458	538.6	59.85	13.67	39.41	6.278	134.7
18.000	.310	58.568	674.1	74.90	17.23	39.13	6.255	168.5
18.000	.409	76.840	874.8	97.20	22.60	38.70	6.221	218.7
18.000	.500	93.451	1053.	117.0	27.49	38.31	6.190	263.3
19.000	.259	51.840	669.6	70.49	15.25	43.91	6.627	158.6
20.000	.272	57.309	820.3	82.03	16.86	48.66	6.976	184.6
20.000	.375	78.599	1113.	111.3	23.12	48.16	6.940	250.5
20.000	.409	85.577	1208.	120.8	25.17	48.00	6.928	271.8
22.000	.301	69.756	1208.	109.8	20.52	58.87	7.672	247.1
22.000	.400	92.276	1584.	144.0	27.14	58.34	7.638	323.9
24.000	.330	83.423	1719.	143.2	24.54	70.05	8.369	322.3
26.000	.362	99.122	2396.	184.3	29.16	82.18	9.065	414.7
28.000	.396	116.746	3272.	233.7	34.34	95.27	9.760	525.8
30.000	.432	136.421	4386.	292.4	40.13	109.3	10.45	658.0

Bending Properties of Square Pipe

Size	Thickness	Weight per foot	Area of section	Moment of inertia	Section modulus	Solid square bar (steel) of same strength		Solid round bar (steel) of same strength		Size of square timber of same strength
						Size	Weight per foot	Size	Weight per foot	
7/8	.134	1.46	.429	.037	.085	1 3/16	2.25	1 5/16	2.35	1 3/4
1	.100	1.25	.367	.049	.098	1 3/16	2.25	1	2.67	1 3/4
1	.125	1.55	.455	.056	.113	7/8	2.60	1 1/16	3.01	1 7/8
1	.188	2.11	.620	.070	.141	1 5/16	2.99	1 1/8	3.38	2
1 1/4	.125	1.97	.579	.120	.192	1 1/16	3.84	1 1/4	4.17	2 1/4
1 1/4	.134	2.05	.603	.125	.201	1 1/16	3.84	1 1/4	4.17	2 1/4
1 1/4	.156	2.29	.673	.138	.222	1 1/8	4.30	1 5/16	4.60	2 3/8
1 1/4	.188	2.48	.729	.154	.247	1 1/8	4.30	1 3/8	5.05	2 1/2
1 1/4	.250	3.28	.964	.177	.283	1 3/16	4.80	1 7/16	5.52	2 5/8
1 1/2	.125	2.33	.685	.218	.291	1 3/16	4.80	1 7/16	5.52	2 5/8
1 1/2	.140	2.55	.750	.237	.316	1 1/4	5.31	1 1/2	6.01	2 5/8
1 1/2	.156	2.78	.817	.255	.341	1 1/4	5.31	1 1/2	6.01	2 3/4
1 1/2	.188	3.05	.897	.288	.385	1 5/16	5.86	1 9/16	6.52	2 7/8
1 1/2	.250	4.00	1.176	.338	.451	1 3/8	6.43	1 11/16	7.60	3
1 11/16	.140	2.76	.811	.348	.412	1 3/8	6.43	1 5/8	7.05	2 7/8
1 11/16	.156	3.00	.882	.377	.447	1 3/8	6.43	1 5/8	7.05	3
1 11/16	.188	3.75	1.103	.428	.508	1 7/16	7.03	1 3/4	8.18	3 1/8
1 11/16	.250	4.60	1.353	.509	.604	1 9/16	8.30	1 13/16	8.77	3 1/4
2	.125	3.10	.911	.551	.551	1 1/2	7.65	1 3/4	8.18	3 1/4
2	.134	3.18	.935	.583	.583	1 1/2	7.65	1 13/16	8.77	3 1/4
2	.145	3.52	1.035	.620	.620	1 9/16	8.30	1 7/8	9.39	3 3/8
2	.188	4.39	1.291	.753	.753	1 5/8	8.98	2	10.68	3 5/8
2	.250	5.40	1.588	.911	.911	1 3/4	10.41	2 1/8	12.06	3 3/4
2 1/2	.188	5.60	1.647	1.559	1.247	1 15/16	12.76	2 5/16	14.28	4 1/4
3	.200	7.06	2.076	2.941	1.961	2 1/4	17.22	2 3/4	20.20	4 7/8

For sections see pages 85 and 86.

All dimensions given in inches.

All weights given in pounds.

In calculating the moments of inertia and section moduli the fillets were disregarded.

The solid bars of same strength are given to the nearest merchant bar size.

The ratio of the flexural strength of steel to that of timber is assumed as ten to one.

Bending Properties of Rectangular Pipe

Size	Thickness	Weight per foot	Area of section	Moment of inertia	Section modulus	Solid square bar (steel) of same strength		Solid round bar (steel) of same strength		Size of square timber of same strength
						Size	Weight per foot	Size	Weight per foot	
1¼×1	.140	1.67	.491	.108	.172	1	3.40	1³⁄₁₆	3.77	2⅛
1¼×1	.188	2.05	.603	.128	.204	1¹⁄₁₆	3.84	1¼	4.17	2¼
1½×1¼	.122	2.05	.603	.185	.247	1⅛	4.30	1⅜	5.05	2½
1½×1¼	.145	2.24	.658	.209	.279	1³⁄₁₆	4.80	1⁷⁄₁₆	5.52	2½
1½×1¼	.156	2.40	.706	.220	.294	1³⁄₁₆	4.80	1⁷⁄₁₆	5.52	2⅝
1½×1¼	.188	2.85	.838	.248	.330	1¼	5.31	1½	6.01	2¾
1½×1¼	.250	3.67	1.079	.289	.385	1⁵⁄₁₆	5.86	1⁹⁄₁₆	6.52	2⅞
2 ×1¼	.134	2.53	.744	.408	.408	1⅜	6.43	1⅝	7.05	2⅞
2 ×1½	.145	3.00	.882	.495	.495	1⁷⁄₁₆	7.03	1¹¹⁄₁₆	7.60	3⅛
2 ×1½	.188	3.61	1.061	.598	.598	1⁹⁄₁₆	8.30	1¹³⁄₁₆	8.77	3⅜
2 ×1½	.250	4.65	1.367	.718	.718	1⅝	8.98	1¹⁵⁄₁₆	10.02	3½
2½×1½	.145	3.52	1.035	.864	.691	1⅝	8.98	1¹⁵⁄₁₆	10.02	3½
2½×1½	.188	4.39	1.291	1.055	.844	1¹¹⁄₁₆	9.68	2	10.68	3¾
2½×1½	.250	5.40	1.588	1.286	1.029	1¹³⁄₁₆	11.17	2¼	13.52	4
3 ×2	.188	5.60	1.647	2.054	1.369	2	13.60	2⁷⁄₁₆	15.86	4⅝
3 ×2	.200	6.00	1.764	2.156	1.437	2¹⁄₁₆	14.46	2⁷⁄₁₆	15.86	4⅝

For sections see pages 87 and 88.

All dimensions given in inches.

All weights given in pounds.

The sections are supposed to have their greatest dimensions in the plane of the loading.

In calculating the moments of inertia and section moduli the fillets were disregarded.

The solid bars of same strength are given to the nearest merchant bar size.

The ratio of the flexural strength of steel to that of timber is assumed as ten to one.

Hydrostatic Test Pressures

Standard Pipe — Black and Galvanized

Size	Weight per foot complete	Test pressure in pounds		Size	Weight per foot complete	Test pressure in pounds	
		Butt	Lap			Butt	Lap
⅛	.245	700		6	19.185	....	1000
¼	.425	700		7	23.769	....	1000
⅜	.568	700		8	25.000	....	800
½	.852	700		8	28.809	....	1000
¾	1.134	700		9	34.188	....	900
1	1.684	700		10	32.000	....	600
1¼	2.281	700	1000	10	35.000	....	800
1½	2.731	700	1000	10	41.132	....	900
2	3.678	700	1000	11	46.247	....	800
2½	5.819	800	1000	12	45.000	....	600
3	7.616	800	1000	12	50.706	....	800
3½	9.202	....	1000	13	55.824	....	700
4	10.889	....	1000	14	60.375	....	700
4½	12.642	....	1000	15	64.500	....	600
5	14.810	....	1000				

Line Pipe

Size	Weight per foot complete	Test pressure in pounds		Size	Weight per foot complete	Test pressure in pounds	
		Butt	Lap			Butt	Lap
⅛	.246	700		6	19.367	....	1500
¼	.426	700		7	23.975	....	1200
⅜	.571	700		8	25.414	....	1000
½	.856	700		8	29.213	....	1200
¾	1.138	700		9	34.612	....	1200
1	1.688	700		10	32.515	....	800
1¼	2.300	1200		10	35.504	....	900
1½	2.748	1200	1700	10	41.644	....	1000
2	3.716	1200	1800	11	46.805	....	900
2½	5.881	1200	1800	12	45.217	....	800
3	7.675	1200	1800	12	50.916	....	900
3½	9.261	....	1700	13	56.649	....	750
4	10.980	....	1600	14	60.802	....	750
4½	12.742	....	1600	15	64.955	....	750
5	14.966	....	1500				

Hydrostatic Test Pressures (Continued)

Drive Pipe

Size	Weight per foot complete	Test pressure in pounds
2	3.730	750
2½	5.906	750
3	7.705	750
3½	9.294	750
4	10.995	750
4½	12.758	750
5	14.989	750
6	19.408	750
7	24.021	750
8	25.495	650
8	29.303	750
8	32.334	750
9	34.711	750
10	32.631	650
10	35.628	750
10	41.785	750
11	46.953	750
12	45.358	600
12	51.067	750
13	56.849	750
14	61.005	750
15	65.161	500
17 O.D.	73.000	500
18 O.D.	81.000	500
20 O.D.	90.000	500

Extra-Strong Pipe — Black and Galvanized

Size	Weight per foot plain ends	Test pressure in pounds	
		Butt	Lap
⅛	.314	700	
¼	.535	700	
⅜	.738	700	
½	1.087	700	
¾	1.473	700	
1	2.171	700	
1¼	2.996	1500	
1½	3.631	1500	2500
2	5.022	1500	2500
2½	7.661	1500	2000
3	10.252	1500	2000
3½	12.505	....	2000
4	14.983	....	2000
4½	17.611	....	1800
5	20.778	....	1800
6	28.573	....	1800
7	38.048	....	1500
8	43.388	....	1500
9	48.728	....	1500
10	54.735	....	1200
11	60.075	....	1100
12	65.415	....	1100
13	72.091	....	1000
14	77.431	....	1000
15	82.771	....	1000

In addition to the above test, on sizes ⅛" to 1" inclusive, the pipe is jarred with a hammer while under pressure.

Oil-Well Tubing

Size	Weight per foot complete	Test pressure in pounds
1¼	2.300	1800
1½	2.748	1800
2	4.000	2200
2	4.500	2500
2½	5.897	2000
2½	6.250	2200
3	7.694	1800
3	8.500	2000
3	10.000	2200
3½	9.261	1500
4	10.980	1500
4	11.750	1800

Double Extra-Strong Pipe — Black and Galvanized

Size	Weight per foot plain ends	Test pressure in pounds	
		Butt	Lap
½	1.714	700	
¾	2.440	700	
1	3.659	700	
1¼	5.214	2200	
1½	6.408	2200	3000
2	9.029	2200	3000
2½	13.695	2200	3000
3	18.583	....	3000
3½	22.850	....	2500
4	27.541	....	2500
4½	32.530	....	2000
5	38.552	....	2000
6	53.160	....	2000
7	63.079	....	2000
8	72.424	....	2000

Hydrostatic Test Pressures (Continued)

Standard Boston Casing

Size	Weight per foot complete	Test pressure in pounds	Size	Weight per foot complete	Test pressure in pounds
2	2.34	750	5⅝	12.00	800
2¼	2.82	750	5⅝	14.00	900
2½	3.25	750	5⅝	17.00	1000
2¾	3.65	750	6¼	12.00	750
3	4.10	750	6¼	13.00	800
3¼	4.60	750	6⅝	13.00	750
3½	5.10	750	6⅝	17.00	900
3¾	5.65	750	7¼	14.75	750
4	6.20	750	7⅝	16.00	750
4¼	6.75	750	7⅝	20.00	800
4¼	9.50	900	8¼	17.50	750
4½	7.25	750	8¼	20.00	800
4½	9.50	900	8¼	24.00	800
4¾	8.00	750	8⅝	19.00	750
5	8.50	750	9⅝	22.75	750
5	10.00	800	10⅝	26.75	750
5	13.00	1000	11⅝	31.50	500
5	16.00	1200	12½	36.50	500
5 3/16	9.00	750	13½	42.00	500
5⅝	10.50	750	14½	47.50	500
			15½	52.50	500

Boston Casing — Pacific Couplings

Size	Weight per foot complete	Test pressure in pounds	Size	Weight per foot complete	Test pressure in pounds
3¾	5.678	750	5⅝	17.033	1000
4	6.223	750	6¼	11.986	750
4¼	6.779	750	6¼	13.046	800
4¼	9.547	900	6¼	13.028	800
4½	7.309	750	6⅝	13.122	750
4½	9.550	900	6⅝	17.076	900
4¾	8.093	750	7⅝	16.038	750
5	8.562	750	7⅝	20.037	800
5	10.071	800	8⅝	19.123	750
5	10.057	800	9⅝	22.802	750
5	13.085	1000	9⅝	30.250	900
5	13.072	1000	10⅝	26.978	750
5	16.062	1200	11⅝	31.872	500
5⅝	10.528	750	12½	36.685	500
5⅝	12.063	800	13½	41.975	500
5⅝	14.069	900	14½	48.018	500
			15½	53.068	500

Hydrostatic Test Pressures (Continued)

California Diamond BX Casing

Size	Weight per foot complete	Test pressure in pounds	Size	Weight per foot complete	Test pressure in pounds
5⅝	20.00	1500	8¼	38.00	1300
6¼	20.00	1400	8¼	43.00	1500
6¼	24.00	1500	9⅝	33.00	1000
6¼	26.00	1600	10	40.00	800
6¼	28.00	1700	10	45.00	900
6⅝	20.00	1200	10	48.00	1000
6⅝	26.00	1400	10	54.00	1200
6⅝	28.00	1500	11⅝	40.00	800
6⅝	30.00	1600	12½	40.00	700
7⅝	26.00	1200	12½	45.00	800
8¼	28.00	1000	12½	50.00	900
8¼	32.00	1100	13½	50.00	800
8¼	36.00	1200	15½	70.00	800

South Penn Casing

Size	Weight per foot complete	Test pressure in pounds	Size	Weight per foot complete	Test pressure in pounds
5³⁄₁₆	13.000	1000	6⅝	24.000	1200
5³⁄₁₆	17.000	1200	8¼	24.000	1000
6¼	13.000	800	8¼	28.000	1200
6¼	17.000	1000	10	32.515	800
6⅝	17.000	900	10	35.000	900
6⅝	20.000	1000	12½	50.000	800

Inserted Joint Casing

Size	Weight per foot plain ends	Test pressure in pounds	Size	Weight per foot plain ends	Test pressure in pounds
2	2.296	750	5⅝	11.789	800
2¼	2.759	750	6¼	11.652	750
2½	3.182	750	6⅝	12.685	750
2¾	3.572	750	7¼	14.390	750
3	4.011	750	7⅝	15.522	750
3¼	4.505	750	8¼	16.940	750
3½	4.988	750	8⅝	18.429	750
3¾	5.532	750	9⅝	21.855	750
4	6.060	750	10⅝	25.780	750
4¼	6.609	750	11⅝	30.512	500
4½	7.131	750	12½	35.243	500
4¾	7.870	750	13½	40.454	500
5	8.328	750	14½	45.714	500
5³⁄₁₆	8.792	750	15½	50.632	500
5⅝	10.222	750			

Hydrostatic Test Pressures (Continued)

Standard Boiler Tubes and Flues — Lap Welded

External diameter	Weight per foot	Test pressure in pounds	External diameter	Weight per foot	Test pressure in pounds
1¾	1.679	750	6	10.282	500
2	1.932	750	7	12.044	500
2¼	2.186	750	8	13.807	500
2½	2.783	750	9	16.955	500
2¾	3.074	750	10	21.240	500
3	3.365	750	11	25.329	500
3¼	4.011	750	12	28.788	500
3½	4.331	750	13	32.439	500
3¾	4.652	750	14	36.424	500
4	5.532	750	15	40.775	500
4½	6.248	500	16	45.359	500
5	7.669	500			

Locomotive Boiler Tubes. Lap Welded — Open-hearth Steel

External diameter	Thickness	Test pressure in pounds	External diameter	Thickness	Test pressure in pounds
1¾	.095	900	2¼	.134	1000
1¾	.109	900	2¼	.135	1000
1¾	.110	900	2¼	.148	1000
1¾	.120	1000	2¼	.150	1000
1¾	.125	1000	2½	.095	800
1¾	.134	1000	2½	.109	800
1¾	.135	1000	2½	.110	800
1¾	.148	1000	2½	.120	800
1¾	.150	1000	2½	.125	800
2	.095	900	2½	.134	900
2	.109	900	2½	.135	900
2	.110	900	2½	.148	1000
2	.120	1000	2½	.150	1000
2	.125	1000	3	.095	750
2	.134	1000	3	.109	750
2	.135	1000	3	.110	750
2	.148	1000	3	.120	750
2	.150	1000	3	.125	750
2¼	.095	900	3	.134	900
2¼	.109	900	3	.135	900
2¼	.110	900	3	.148	1000
2¼	.120	1000	3	.150	1000
2¼	.125	1000			

Hydrostatic Test Pressures (Continued)

Matheson Joint Pipe

External diameter	Weight per foot complete	Test pressure in pounds	External diameter	Weight per foot complete	Test pressure in pounds
2	1.952	700	13	42.472	650
3	3.392	700	14	31.536	500
4	5.339	600	14	37.324	550
5	7.019	600	14	45.941	600
6	8.872	600	15	35.686	500
7	11.028	600	15	41.581	550
8	13.405	600	15	50.826	600
8	15.614	700	16	40.089	500
9	15.945	500	16	46.050	550
9	18.621	600	16	55.923	600
9	23.557	700	17	43.687	450
10	18.610	500	18	47.384	450
10	22.001	600	18	59.501	500
10	28.309	700	19	52.815	450
11	21.638	500	20	58.332	450
11	25.600	600	20	79.631	500
11	33.445	700	22	71.098	450
12	24.880	500	22	93.629	500
12	31.057	600	24	84.882	450
12	39.129	700	26	100.697	450
13	28.060	500	28	119.021	450
13	34.095	600	30	138.851	450

Reamed and Drifted Pipe

Size	Weight per foot complete	Test pressure in pounds		Size	Weight per foot complete	Test pressure in pounds	
		Butt	Lap			Butt	Lap
2	3.697	1000	1500	4	10.980	....	1000
2	4.000	....	1800	4½	12.742	....	1000
2½	5.843	1000	1500	5	14.966	....	1000
3	7.675	1000	1500	6	19.367	....	1000
3½	9.261	....	1000				

Air Line Pipe

Size	Weight per foot complete	Test pressure in pounds	Size	Weight per foot complete	Test pressure in pounds
1½	3.000	2000	4	11.750	1800
2	4.000	2000	5	17.000	1700
2½	6.500	2000	6	21.000	1600
3	9.000	2000			

Hydrostatic Test Pressures (Continued)

Converse Lock Joint Pipe

External diameter	Weight per foot complete	Test pressure in pounds	External diameter	Weight per foot complete	Test pressure in pounds
2	2.207	700	13	45.387	650
3	3.931	700	14	35.013	500
4	5.991	600	14	40.714	550
5	7.932	600	14	49.204	600
6	9.969	600	15	39.731	500
7	12.419	600	15	45.538	550
8	15.008	600	15	54.646	600
8	17.190	700	16	45.847	500
9	17.958	500	16	51.713	550
9	20.602	600	16	61.428	600
9	25.477	700	17	49.850	450
10	20.801	500	18	55.123	450
10	24.148	600	18	67.030	500
10	30.375	700	19	61.081	450
11	23.963	500	20	68.337	450
11	27.875	600	20	89.244	500
11	35.619	700	22	82.868	450
12	27.795	500	22	104.958	500
12	33.885	600	24	99.789	450
12	41.844	700	26	120.555	450
13	31.179	500	28	142.000	450
13	37.129	600	30	166.828	450

Kimberley Joint Pipe

External diameter	Weight per foot complete	Test pressure in pounds	External diameter	Weight per foot complete	Test pressure in pounds
6	9.623	600	14	38.657	550
7	11.930	600	14	47.269	600
8	14.371	600	15	37.094	500
8	16.579	700	15	42.986	550
9	17.032	500	15	52.226	600
9	19.707	600	16	41.596	500
9	24 640	700	16	47.554	550
10	19 779	500	16	57.422	600
10	23.169	600	17	47.737	450
10	29.474	700	18	51.486	450
11	22.924	500	18	63.596	500
11	26.884	600	19	57.118	450
11	34.727	700	20	62.865	450
12	26.128	500	20	84.154	500
12	32.302	600	22	75.839	450
12	40.370	700	22	98.359	500
13	29.443	500	24	90.034	450
13	35.475	600	26	106.260	450
13	43.848	650	28	124.413	450
14	32.873	500	30	144.616	450

Hydrostatic Test Pressures (Continued)

Allison Vanishing Thread Tubing — Ends Upset

Size	Weight per foot complete	Test pressure in pounds	Size	Weight per foot complete	Test pressure in pounds
2	3.731	1800	4½	12.744	1500
2½	5.903	2100	5	14.962	1500
3	7.699	1900	6	19.359	1500
3½	9.287	1500	7	23.957	1200
4	10.984	1500	8	29.196	1200

Allison Vanishing Thread Tubing — Not Upset

Size	Weight per foot complete	Test pressure in pounds	Size	Weight per foot complete	Test pressure in pounds
1¼	2.303	1200	4	10.973	1500
1½	2.751	1700	4½	12.733	1500
2	3.723	1700	5	14.946	1500
2½	5.893	2000	6	19.338	1500
3	7.689	1800	7	23.936	1200
3½	9.276	1500	8	29.167	1200

Flush Joint Tubing

Size	Weight per foot plain ends	Test pressure in pounds	Size	Weight per foot plain ends	Test pressure in pounds
3	7.575	1000	9 O.D.	31.624	900
3½	9.109	1000	9	33.907	900
4	10 790	1000	10 O.D.	37.559	900
4½	12.538	1000	10	40.483	900
5	14.617	1000	12 O.D.	46.558	800
6 O.D.	17.105	1000	12	49.562	800
6	18.974	1000	13	63.441	800
7 O.D.	21.535	1000	14	68.119	750
7	23.544	1000	15	82 771	750
8 O.D.	26.404	1000	18 O.D.	93.451	750
8	28.554	1000			

Test applied on pipe prior to threading.

Hydrostatic Test Pressures (Concluded)

Dry Kiln Pipe

Size	Weight per foot complete	Test pressure in pounds
1	1.697	700
1¼	2.304	700

In addition to the above test the pipe is jarred with a hammer while under pressure.

Full Weight Drill Pipe

Size	Weight per foot complete	Test pressure in pounds
4	11.055	1500
4	11.815	1500
4½	12.744	1500
5	15.055	1500
6	19.463	1500

Special Rotary Pipe

Size	Weight per foot complete	Test pressure in pounds
2½	7.830	2000
2½	10.000	2500
4	12.500	1800
4	15.000	2000
4½	15.500	1600
4½	18.000	1800
5	17.500	1600
5	21.000	1800
6	23.500	1500
6	29.000	1800

Tuyere Pipe

Size	Weight per foot plain ends	Test pressure in pounds
1	2.171	700
1¼	2.996	1500

California Diamond BX Drive Pipe

Size	Weight per foot complete	Test pressure in pounds
4¼	16.000	1800
4½	12.850	1400
4½	15.000	1700

In addition to the above test the pipe is jarred with a hammer while under pressure.

Special Upset Rotary Pipe

Size	Weight per foot complete	Test pressure in pounds
2½	7.841	2000
2½	10.000	2500
4	12.632	1800
4	15.323	2000
5	17.000	1600
5	20.000	1900
6	19.551	1500
6	28.948	1800

California Special External Upset Tubing

Size	Weight per foot complete	Test pressure in pounds
3	8.627	2000
4	12.500	1800

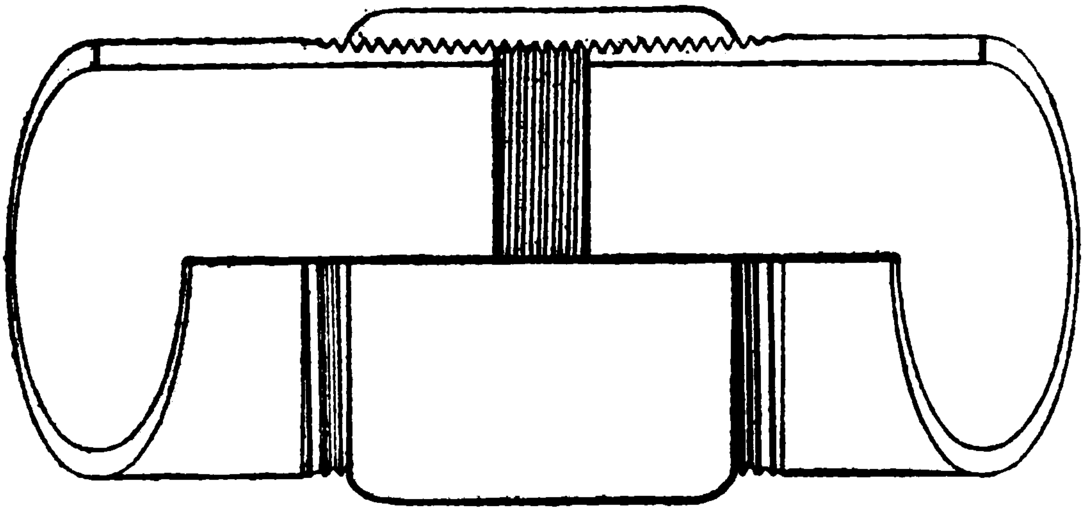


Fig. 5. Typical Section of Standard Pipe Coupling and Joint
(For list of sizes, dimensions and weights see page 22.)

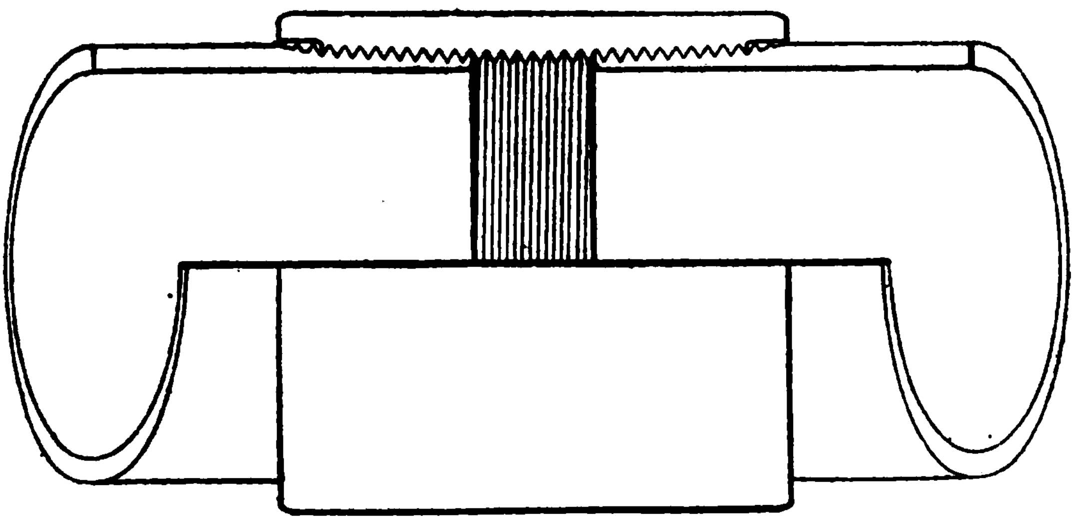


Fig. 6. Typical Section of Line Pipe Coupling and Joint
(For list of sizes, dimensions and weights see page 23.)

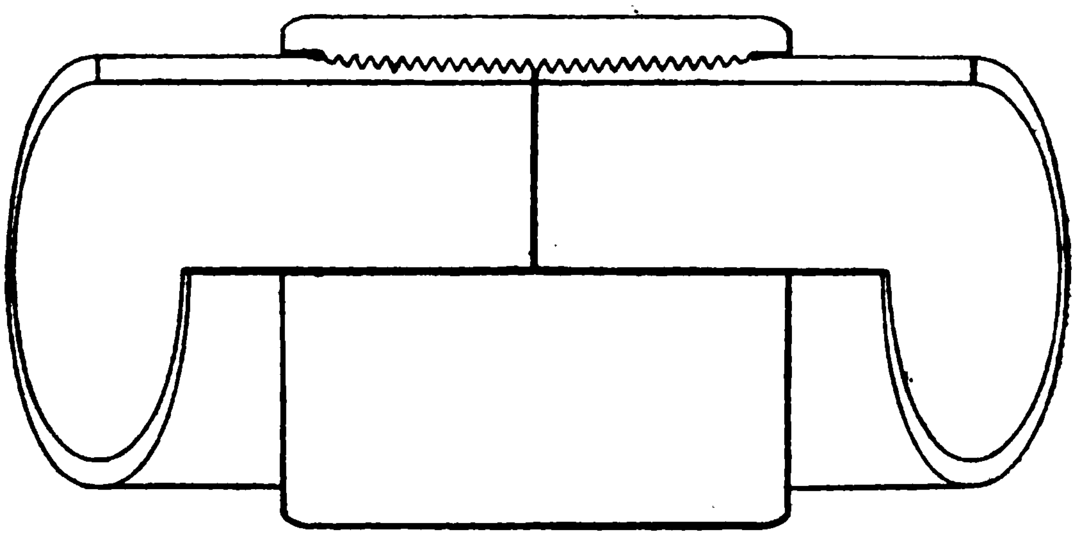


Fig. 7. Typical Section of Drive Pipe Coupling and Joint
(For list of sizes, dimensions and weights see page 24.)

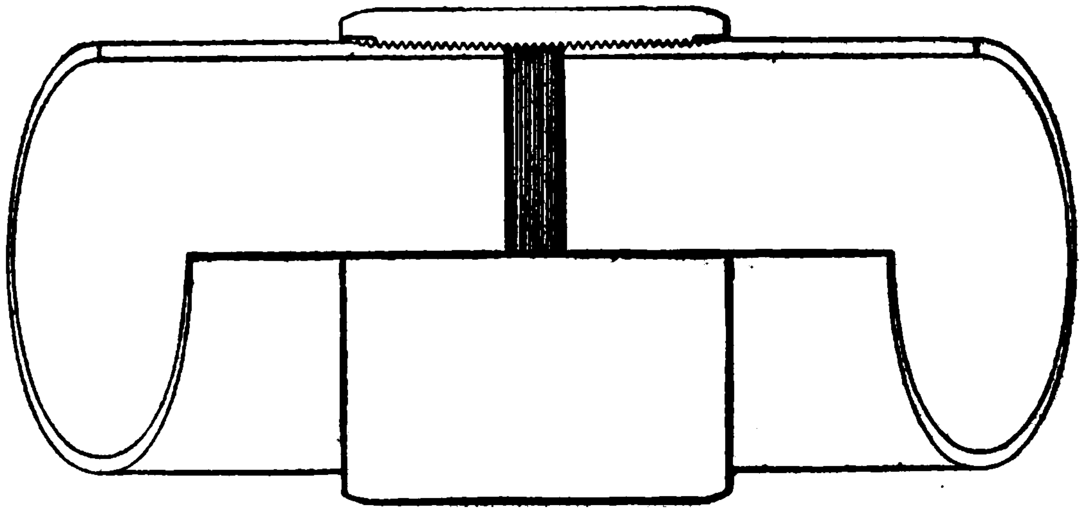


Fig. 8. Typical Section of Standard Boston Casing Coupling and Joint
(For list of sizes, dimensions and weights see page 26.)

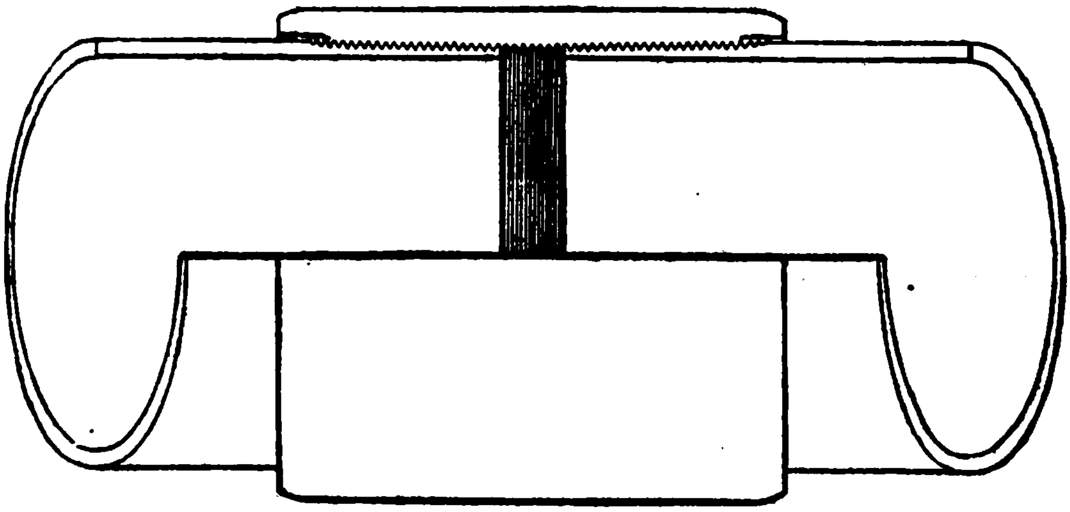


Fig. 9. Typical Section of Boston Casing — Pacific Coupling and Joint
(For list of sizes, dimensions and weights see page 28.)

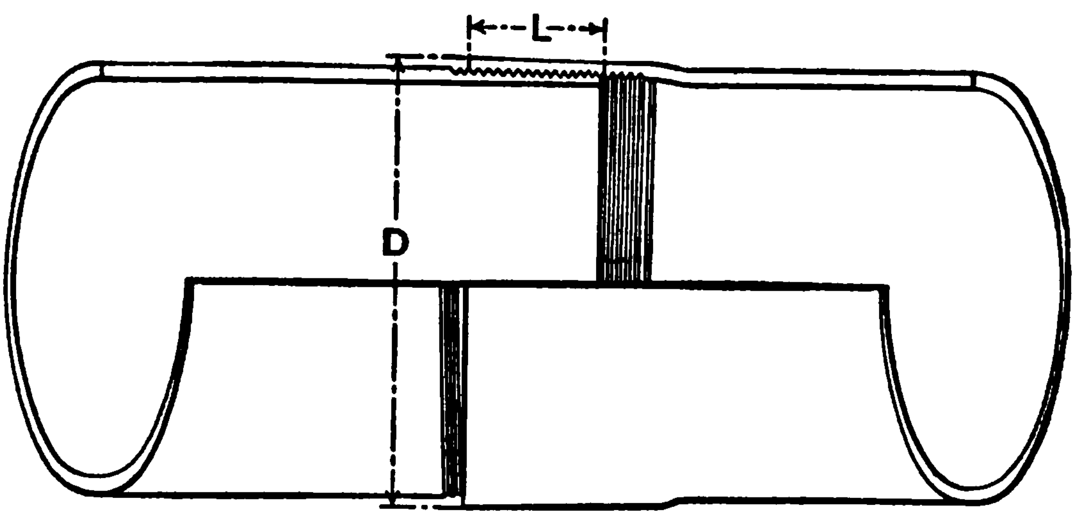


Fig. 10. Typical Section of Inserted Joint Casing
(For list of sizes, dimensions and weights see page 27.)

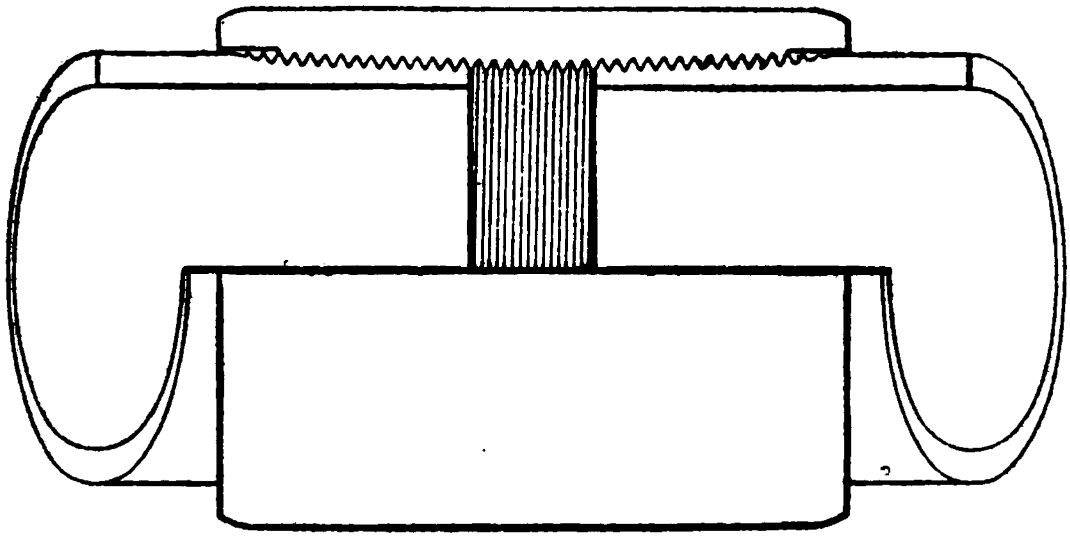


Fig. 11. Typical Section of Special Rotary Pipe Coupling and Joint
(For list of sizes, dimensions and weights see page 34.)

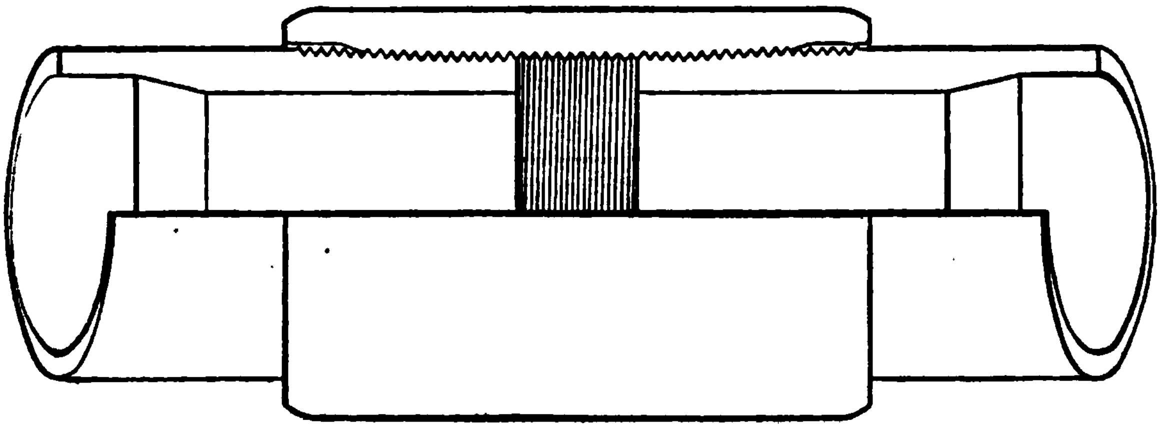


Fig. 12. Typical Section of Special Upset Rotary Pipe Coupling and Joint
(For list of sizes, dimensions and weights see page 34.)

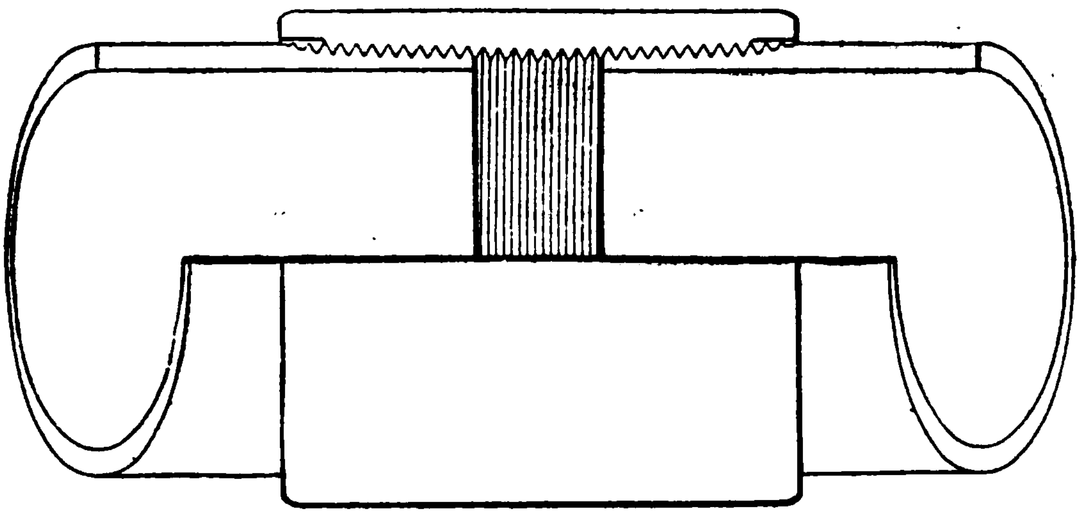


Fig. 13. Typical Section of Reamed and Drifted Pipe Coupling and Joint
(For list of sizes, dimensions and weights see page 35.)

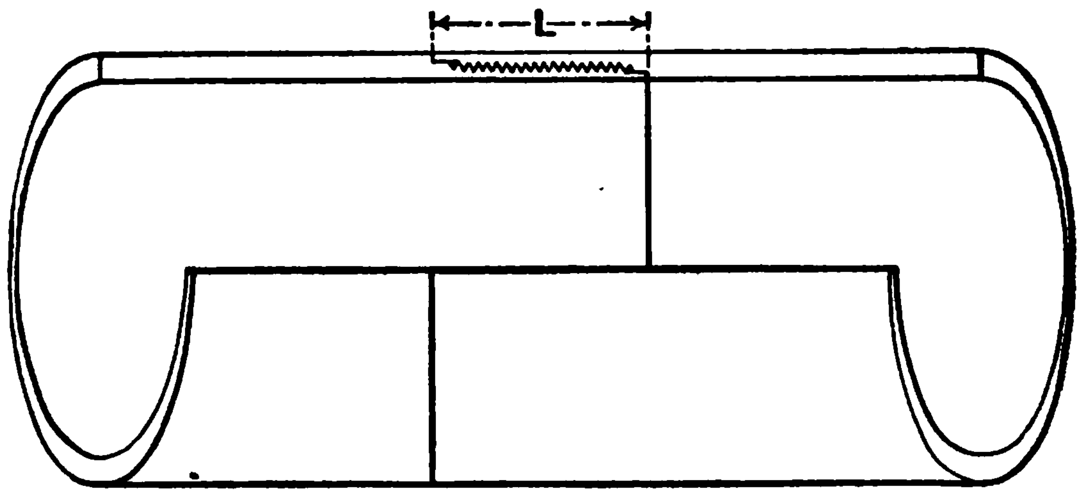


Fig. 14. Typical Section of Flush Joint Tubing
(For list of sizes, dimensions and weights see page 32.)

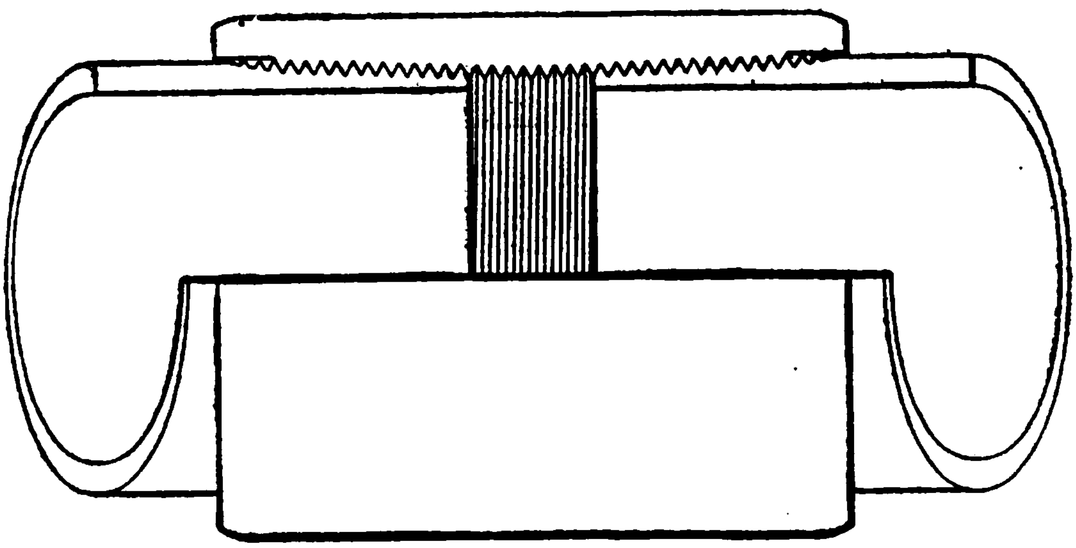


Fig. 15. Typical Section of Full Weight Drill Pipe Coupling and Joint
(For list of sizes, dimensions and weights see page 36.)

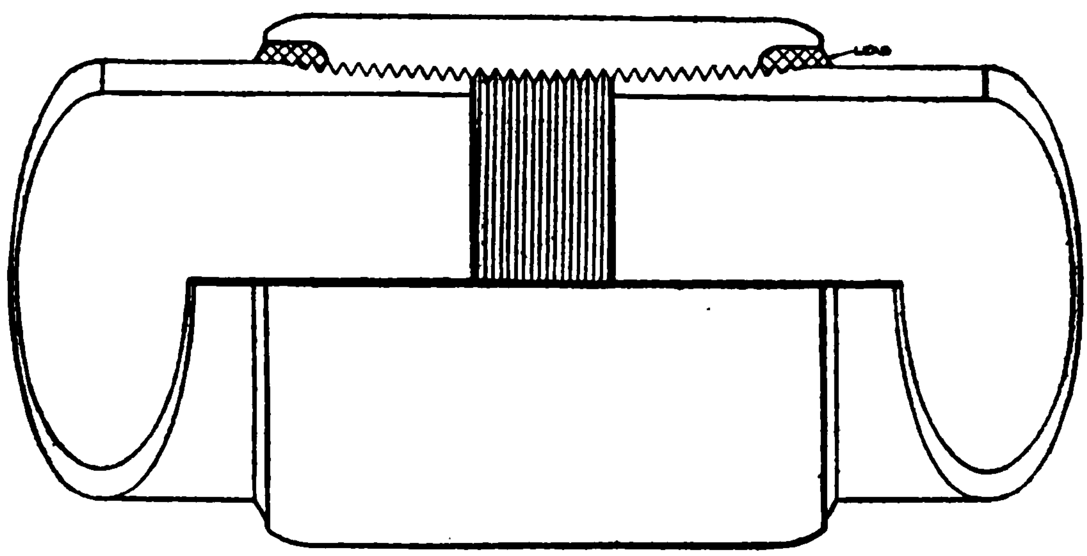


Fig. 16. Typical Section of Air Line Pipe Coupling and Joint
(For list of sizes, dimensions and weights see page 36.)

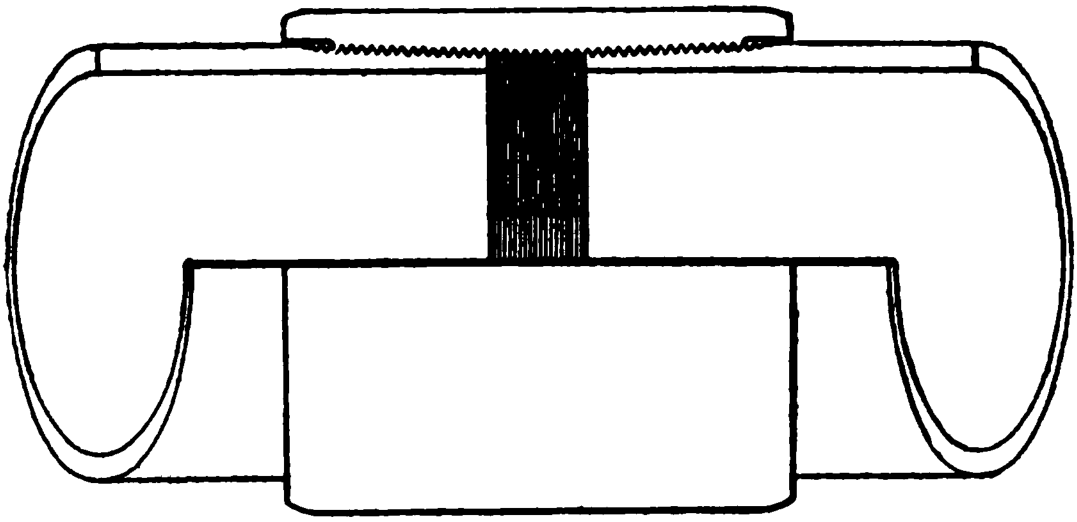


Fig. 17. Typical Section of Oil Well Tubing Coupling and Joint
(For list of sizes, dimensions and weights see page 30.)

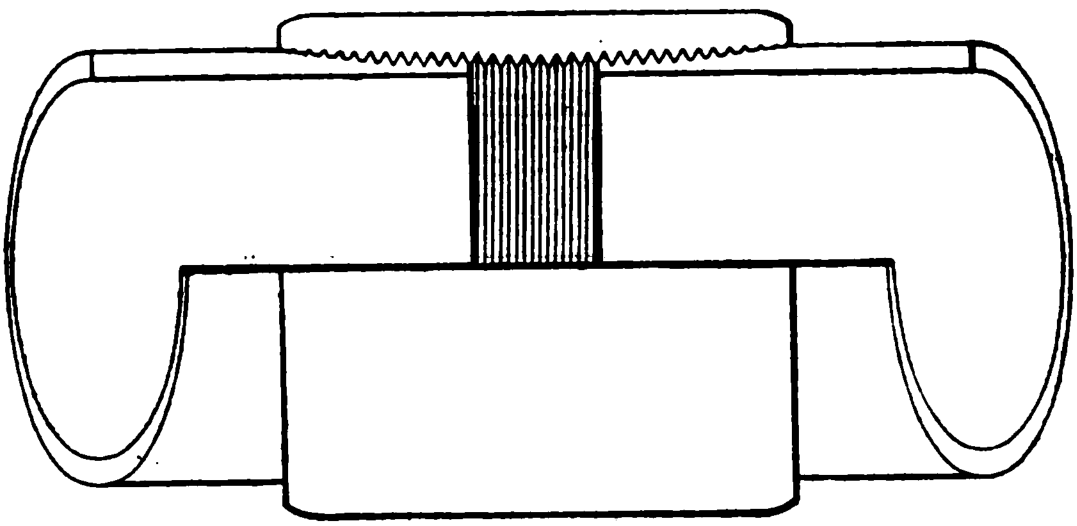


Fig. 18. Typical Section of Allison Vanishing Thread Tubing Coupling and Joint—Not Upset
(For list of sizes, dimensions and weights see page 33.)

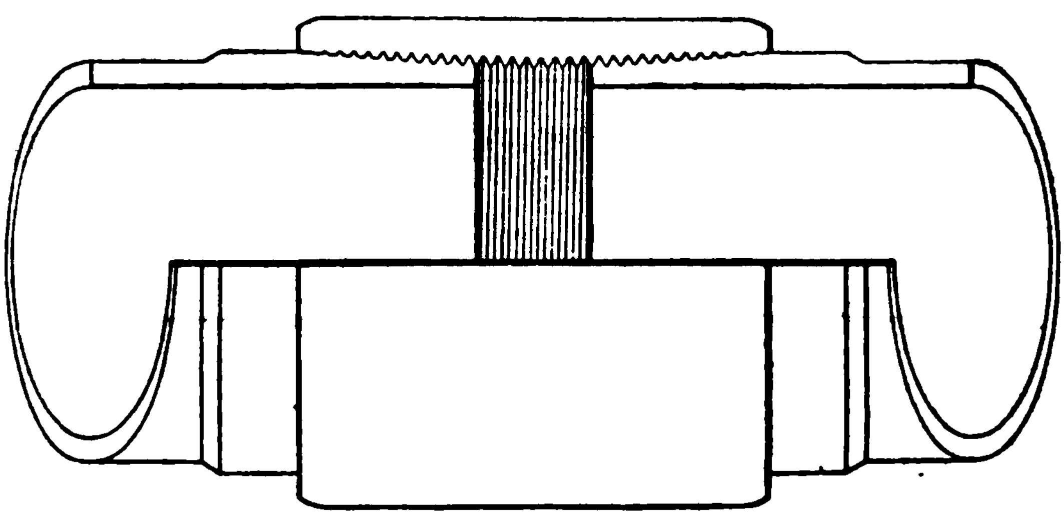


Fig. 19. Typical Section of Allison Vanishing Thread Tubing Coupling and Joint—Ends Upset
(For list of sizes, dimensions and weights see page 33.)

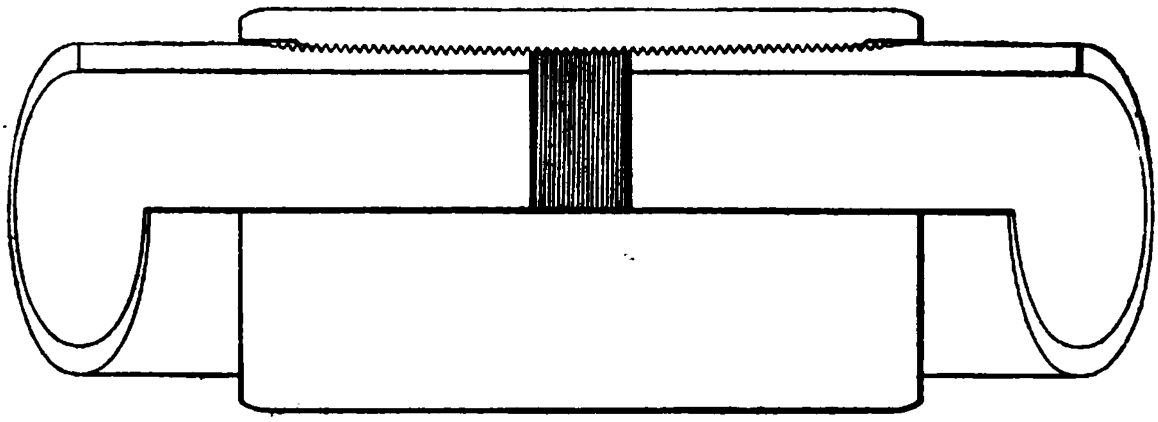


Fig. 20. Typical Section of California Diamond BX Casing Coupling and Joint
(For list of sizes, dimensions and weights see page 29.)

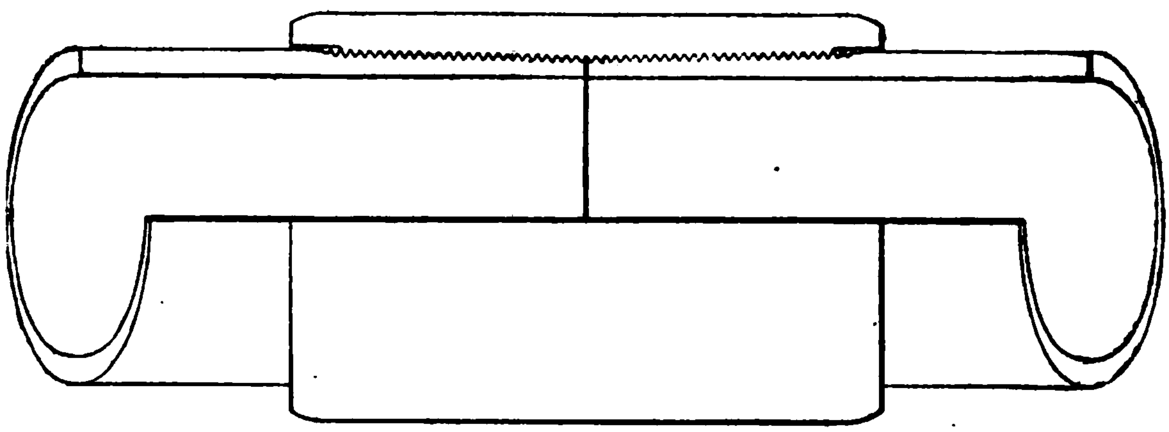


Fig. 21. Typical Section of California Diamond BX Drive Pipe Coupling and Joint
(For list of sizes, dimensions and weights see page 31.)

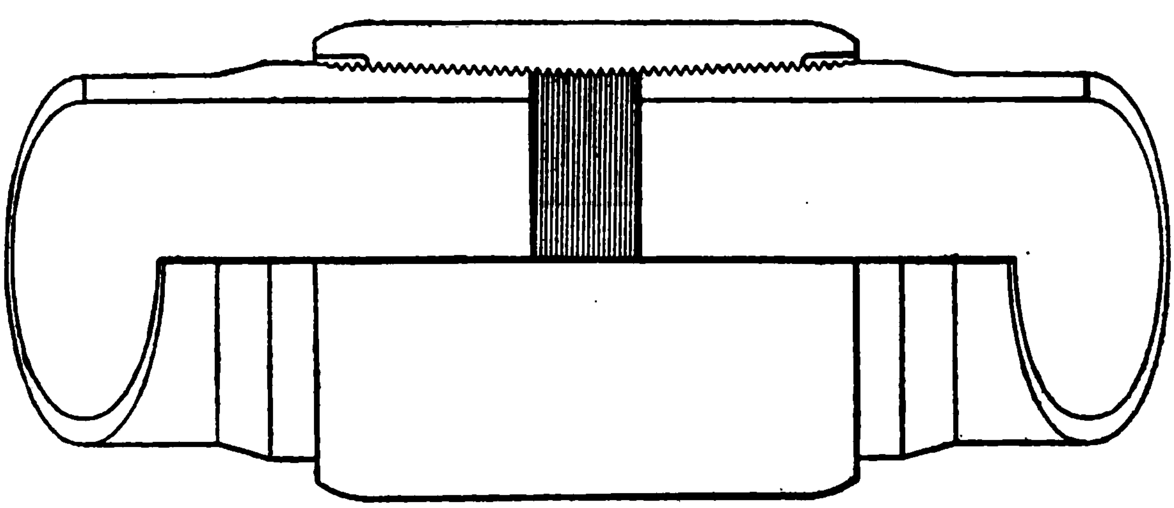


Fig. 22. Typical Section of California Special External Upset Tubing
(For list of sizes, dimensions and weights see page 30.)

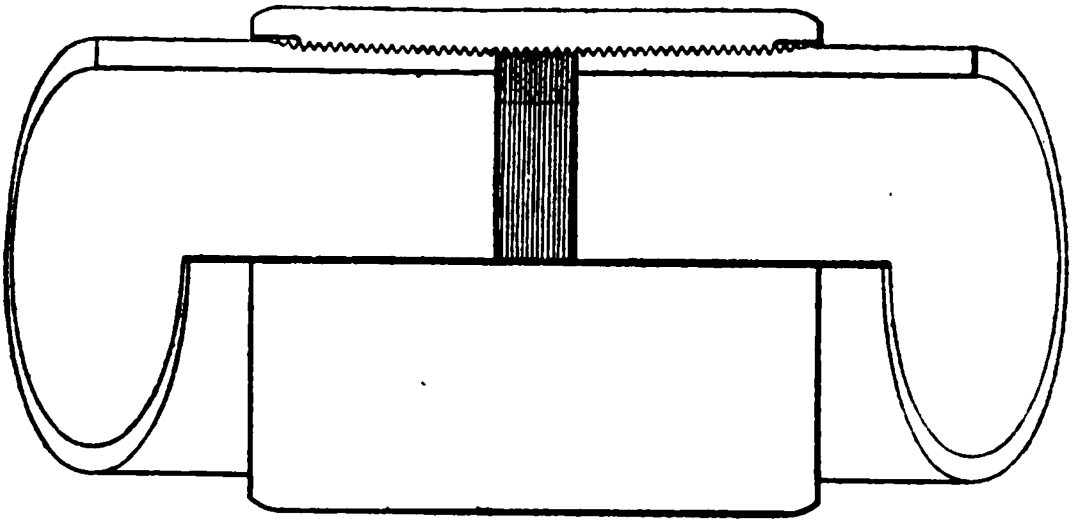


Fig. 23. Typical Section of South Penn Casing Coupling and Joint
(For list of sizes, dimensions and weights see page 35.)

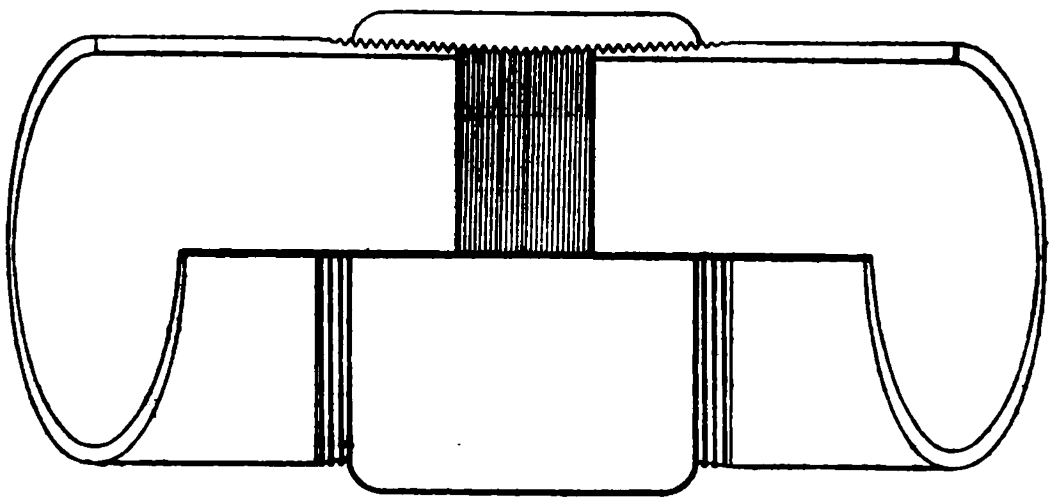


Fig. 24. Typical Section of Dry Kiln Pipe Coupling and Joint
(For list of sizes, dimensions and weights see page 37.)

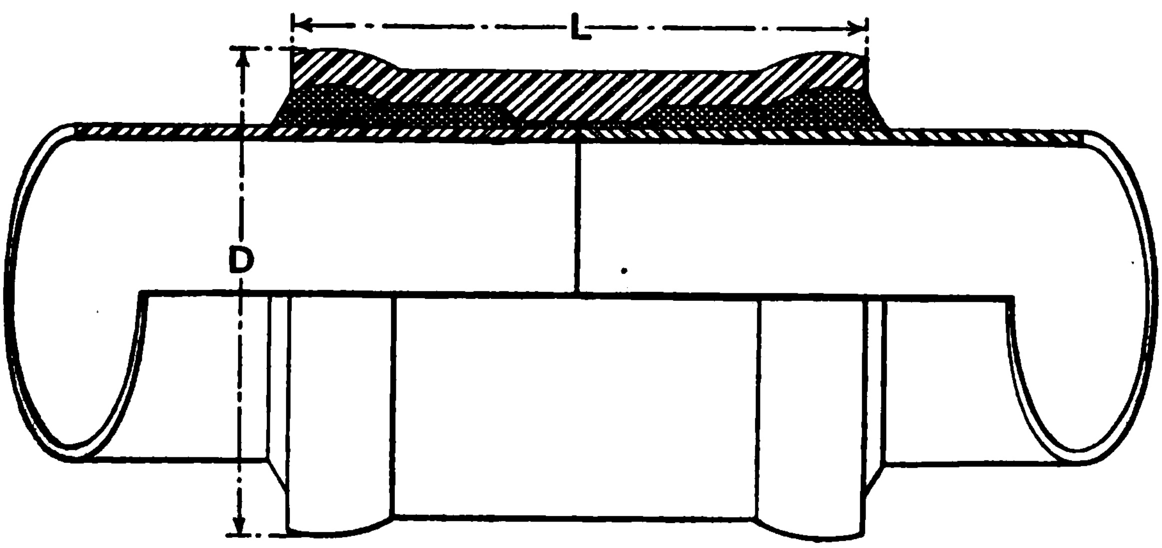


Fig. 25. Typical Section of a Kimberley Joint
(For list of sizes, dimensions and weights see page 44.)

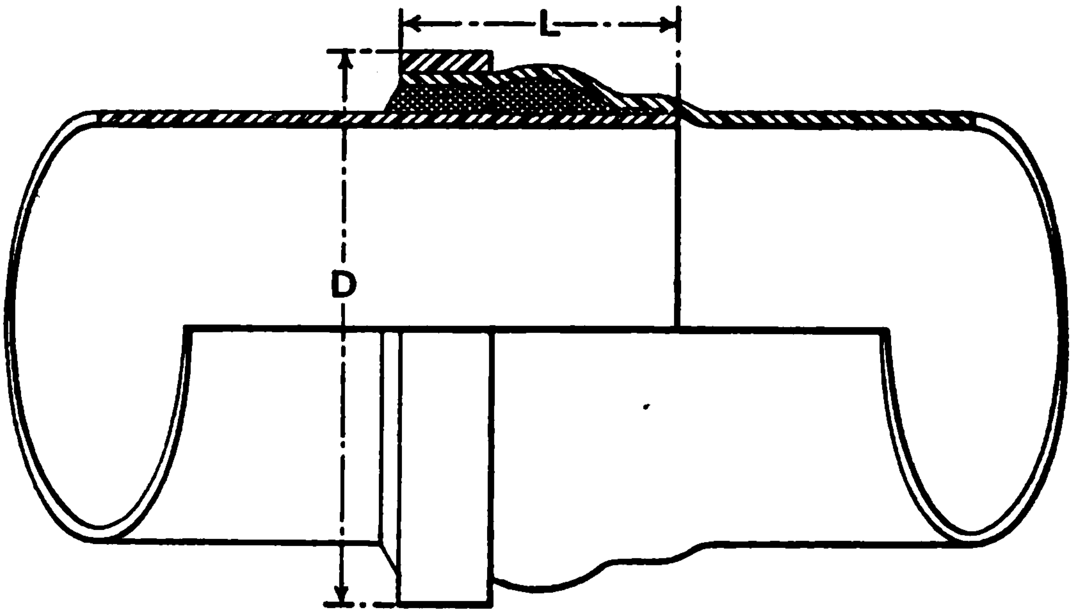


Fig. 26. Typical Section of a Matheson Joint
(For list of sizes, dimensions and weights see page 42.)

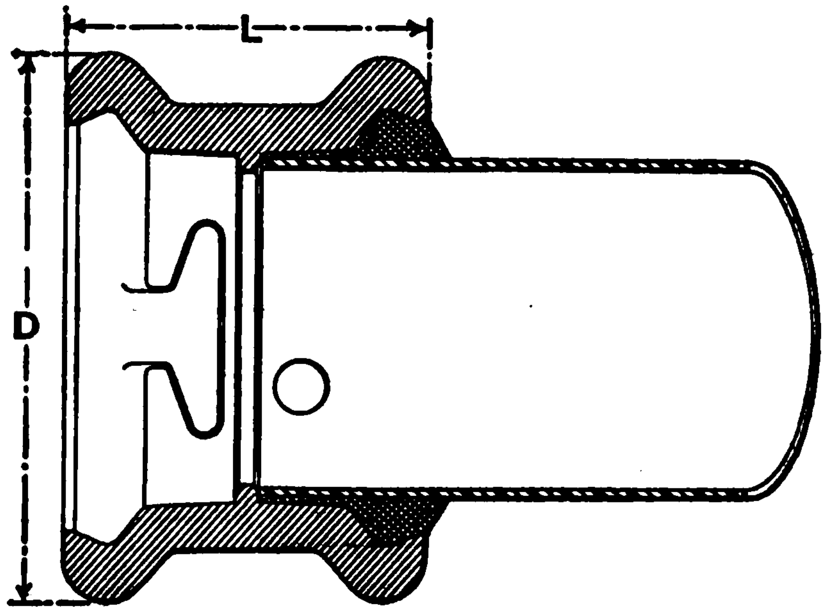


Fig. 27. Typical Section of a Converse Lock Joint Hub
(For list of sizes, dimensions and weights see page 43.)

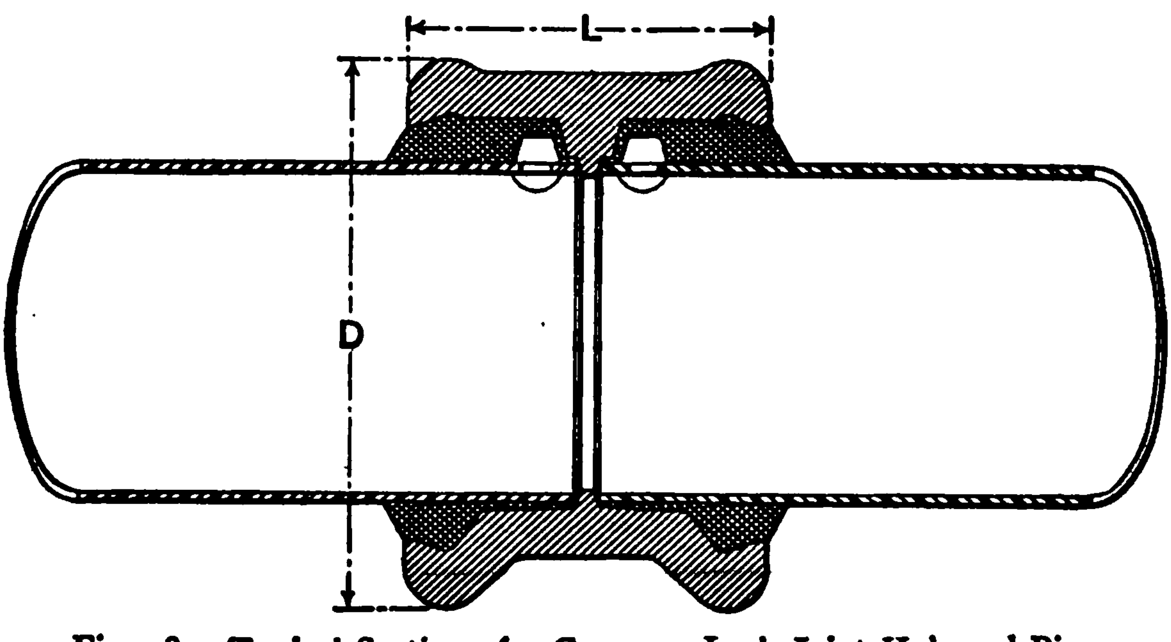


Fig. 28. Typical Section of a Converse Lock Joint Hub and Pipe
(For list of sizes, dimensions and weights see page 43.)

Sections of Square Pipe

Fig. 29

Fig. 32

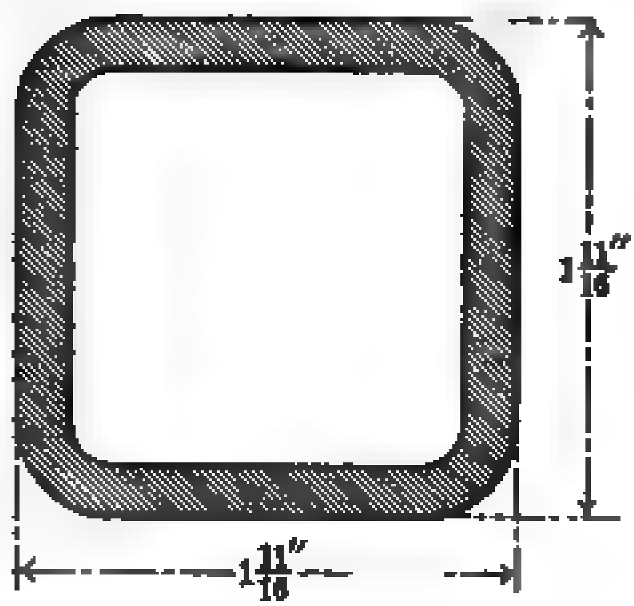


Fig. 33

Fig. 30

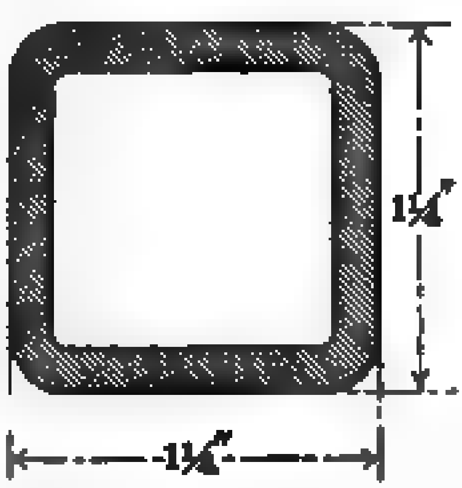


Fig. 31

Fig. 34

See table, page 45, for various thicknesses and weights manufactured.

Sections of Square Pipe

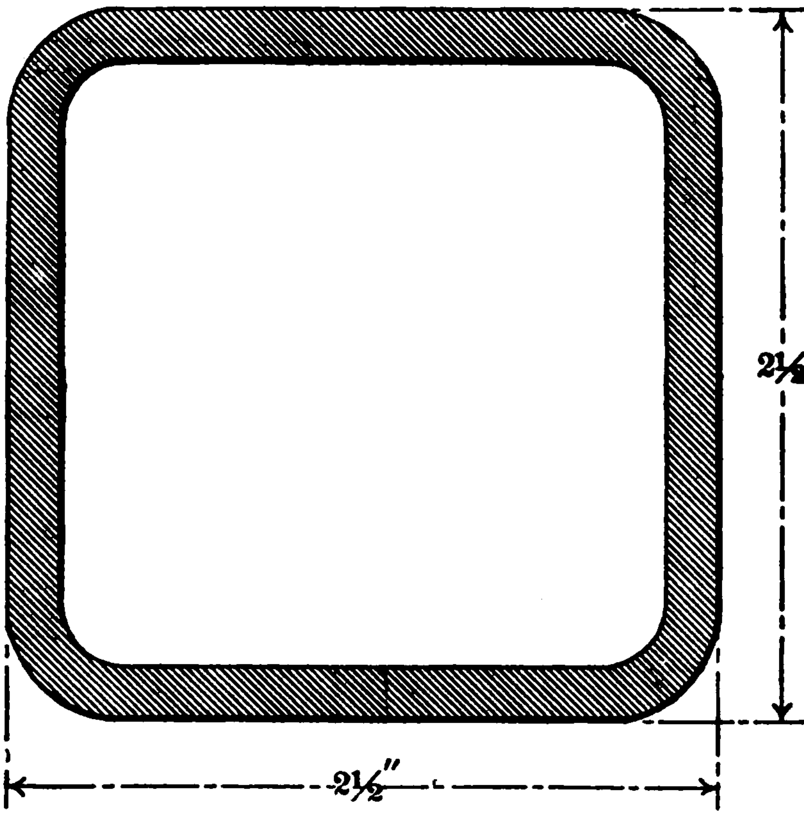


Fig. 35

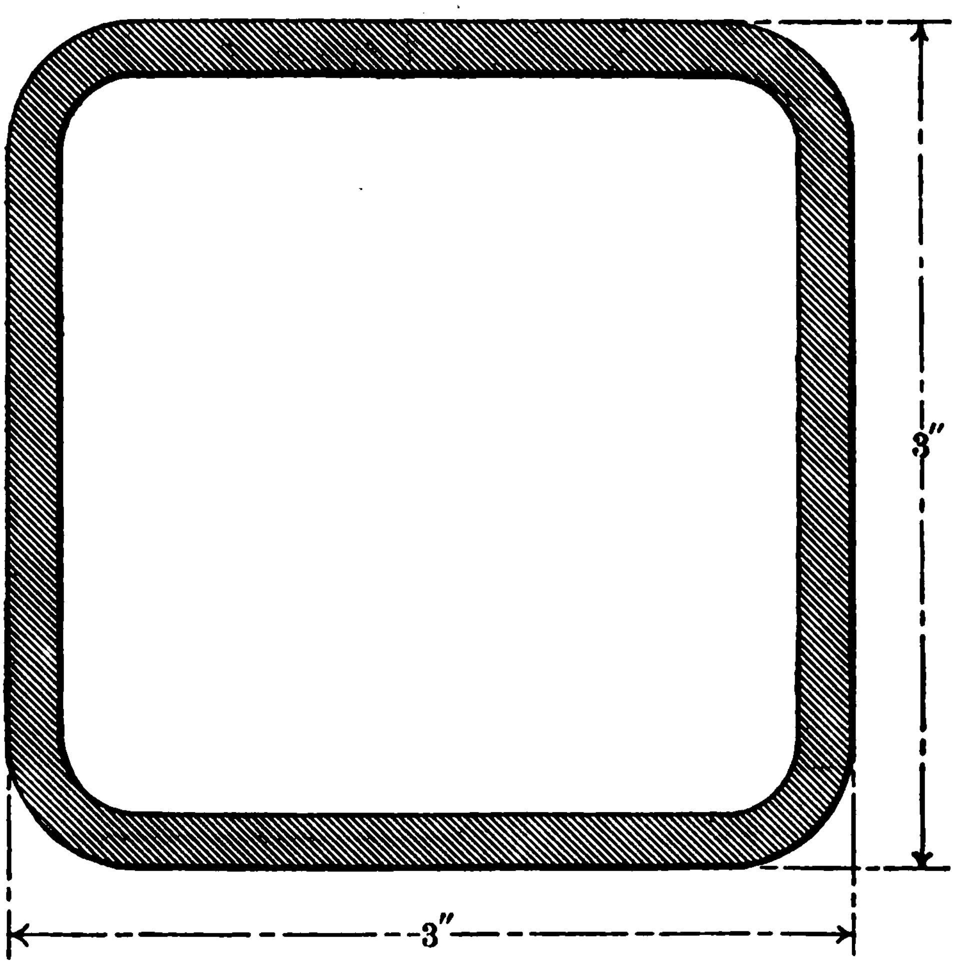


Fig. 36

See table, page 45, for various thicknesses and weights manufactured.

Sections of Rectangular Pipe

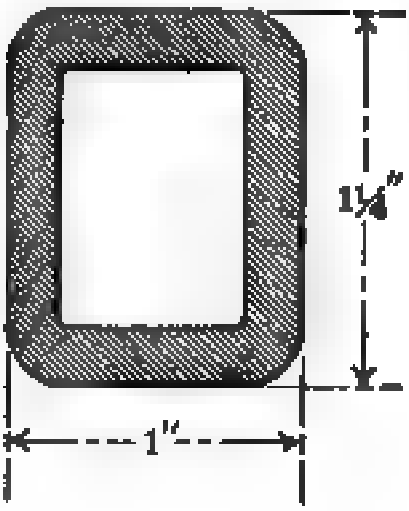


Fig. 37

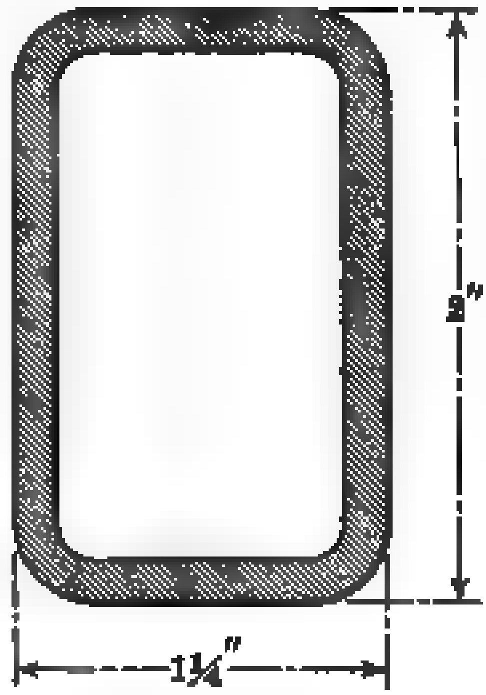


Fig. 39

Fig. 38

Fig. 40

See table, page 45, for various thicknesses and weights manufactured.

Sections of Rectangular Pipe

Fig. 41

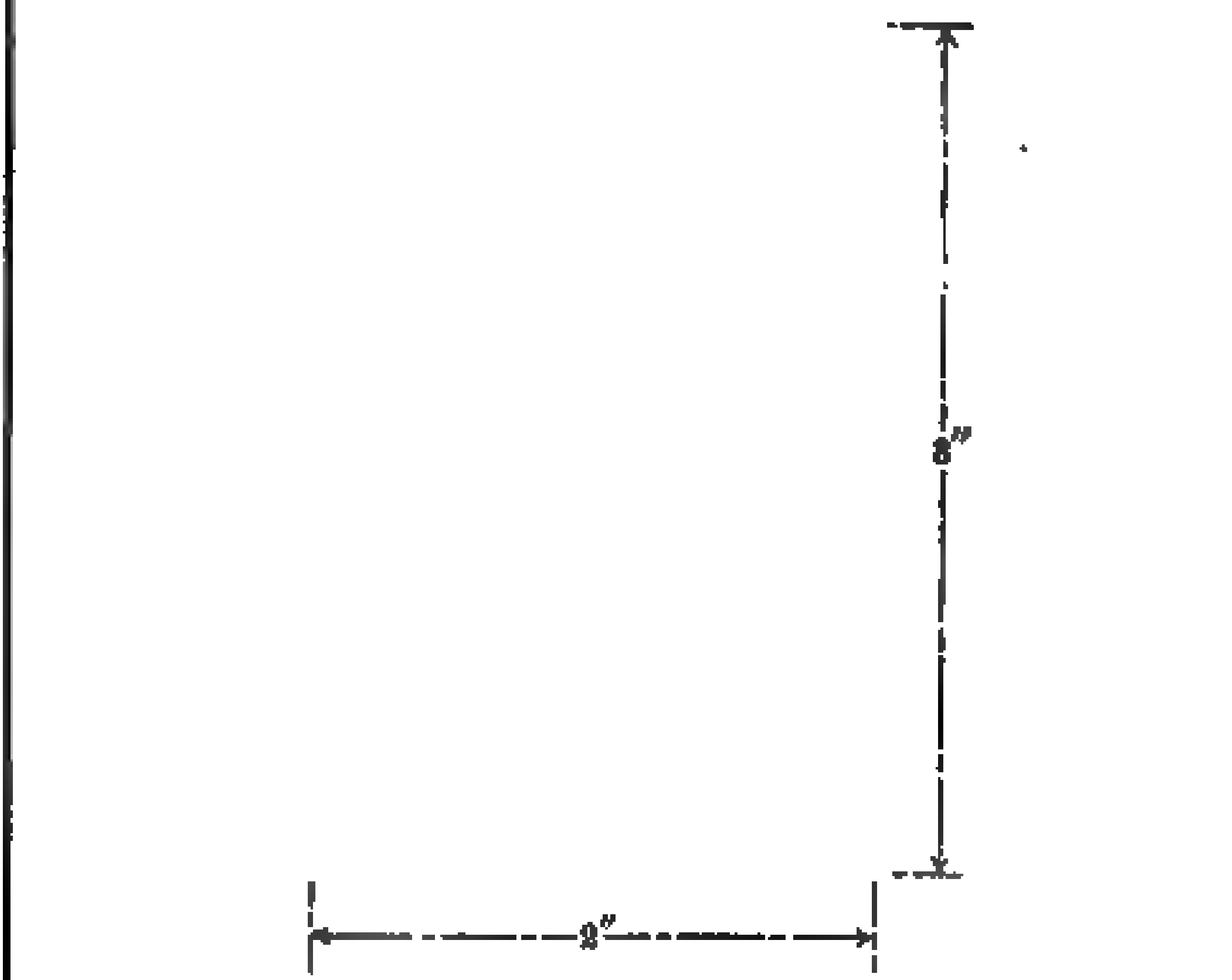


Fig. 42

See table, page 45, for various thicknesses and weights manufactured.

STANDARD SPECIFICATIONS

It is the aim, as the reader will see by the system of testing and inspection heretofore described, to ship nothing but first-class material. Most orders specify "Steel Pipe" and rely on mill tests for the necessary inspection, which, as a matter of fact, are often more severe than those specified by customers. It sometimes happens, however, that specifications contain requirements which are unreasonable, in that they increase the cost of manufacture without safeguarding the customer's interests by eliminating defective material — such as, for example, tests to be made on the skelp before welding, which would result in some cases in the rejection of good steel plates because they happened to be rolled a little above or below the customary temperature, and might, on the other hand, allow defective plates to go through to finished pipe. It is evidently much better to apply all tests after the skelp has been through the welding furnace and is in the form of finished pipe, for good steel may be ruined by improper heating in welding.

For standard pipe (lap or butt-welded) we suggest the following specification, which will insure first-class material without unnecessarily increasing the cost of manufacture. These specifications illustrate the method of testing generally applicable to tubes and pipe, in order to insure uniformity and good quality material and workmanship.

We also give our standard specifications for locomotive boiler tubes, which are fully as strict, if not more so, than any we are required to work to. It would greatly facilitate the work of inspection if the tests required on tubes and pipes were standardized. We trust that these specifications will meet the approval of engineers, architects, and others who wish to protect their interests, as they have been prepared after careful consideration with that end in view.

The following specifications are known as the 1913 Book of Standards specifications.

SPECIFICATION FOR STANDARD WELDED PIPE

1. **Material.** Welded pipe is to be made of uniformly good quality soft weldable steel, rolled from solid ingots. Sufficient crop shall be cut from the ends to insure sound material, and the steel shall be given the most approved treatment in heating and rolling.

2. **Process of Manufacture.** All pipe shall be made either by the lap or butt-weld process as specified on order according to the best methods and practice.

3. **Surface Inspection.** The pipe must be reasonably straight and free from blisters, cracks or other injurious defects. Liquor marks incidental to the manufacture of lap-welded pipe will not be considered as surface defects. The pipe shall not vary more than one per cent either way from being perfectly round or true to the standard outside diameter, except on the small sizes, where a variation of one-sixty-fourth

of an inch will be accepted. The pipe must not vary more than five per cent either way from standard weight.

4. **Threading and Reaming.** Where required, the pipe must have a good Briggs standard thread, which will make a tight joint when tested by internal hydrostatic pressure at the mill (paragraph 5). The thread must not vary more than one and one-half turns either way when tested with a Pratt & Whitney Briggs standard gage. All burrs at the ends are to be removed.

5. **Internal Pressure Test.** The following test pressures will be applied to the respective sizes of standard Butt and Lap-weld pipe as indicated in table:

Nominal size	Method of manufacture	Test pressure
1/8 inch to 2 inches (inclusive)....	Butt Weld	700 pounds
2 1/2 inches and 3 inches..........	Butt Weld	800 pounds
Up to 8 inches.................	Lap Weld	1000 pounds
9 and 10 inches................	Lap Weld	900 pounds
11 and 12 inches................	Lap Weld	800 pounds
13 and 14 inches................	Lap Weld	700 pounds
15 inches.....................	Lap Weld	600 pounds

NOTE. On 8, 10 and 12 inch sizes which have more than one weight as standard, we have shown the hydraulic test pressure for the heaviest weight.

6. **Testing of Material.** The steel from which the pipe is made must show the following physical properties:

Pipe Steel

Tensile Strength..........	52 000 to 62 000 pounds per square inch.
Elastic Limit	Not less than 30 000 pounds per square inch.
Elongation in 8 Inches.....	Not less than 20%.
Reduction in Area.........	Not less than 50%.

A test piece cut lengthwise from the pipe and filed smooth on the edges should bend through 180 degrees with an inner diameter at the bend equal to the thickness of the material, without fracture.

7. **Couplings.** The material to be sound and free from injurious defects. Threads must be clean cut, tapped straight through and of such pitch diameter as will make a tight joint. The ends must be countersunk.

8. **Thread Protection.** Solid tapped rings or split couplings will be provided as thread protectors on all sizes 4 inches in diameter or larger. Protection will be provided for smaller sizes when specifically called for on order.

9. All tests shall be made at mill.

SPECIFICATION FOR MATHESON JOINT PIPE

1. **General Description of Pipe.** The pipe shall be made of uniformly good quality soft welding steel rolled from solid ingots. Sufficient crop shall be cut from the ends to insure sound material. The pipe shall be manufactured by what is known in the trade as the lap-weld process and each length shall be fitted with Matheson Joint.

2. **Design of Joint.** The joint shall be made according to the schedule of dimensions and weights given on page 42, as closely as it is practicable to work, especial attention being directed to having the bell circular and the diameter of the mouth of the bell tc standard size, in order to allow the lead to flow and be calked when a slight deflection is made at a joint. Also the depth of insertion must not be materially increased, in order to not materially increase the length required to lay the line. In cases where a greater thickness is specified than shown in the schedule, the form of the bell shall be that for the next larger diameter on the schedule having about the same thickness.

3. **Surface Inspection.** The pipe must be reasonably straight and free from blisters, cracks or other injurious defects. Liquor marks incidental to the manufacture of lap-welded pipe will not be considered as surface defects. The pipe shall not vary more than 1 per cent either way from the mean outside diameter specified. The pipe must not vary more than 5 per cent either way from weight as listed; any piece selected for test must be at least eighteen feet long. Shorter lengths may be more than 5 per cent over weight, but must not be more than 5 per cent under weight.

4. **Strength of Material.** The steel used shall show the following physical properties on test pieces cut from finished pipe:

Pipe Steel

Tensile strength..........	52 000 to 62 000 pounds per square inch.
Elastic limit.............	Not less than 30 000 pounds per square inch.
Elongation in 8 inches.....	Not less than 20%.
Reduction in area........	Not less than 50%.

5. **Internal Pressure Test.** Each piece of pipe shall be tested to a hydrostatic pressure not less than that shown in table, page 73, without showing any leak or injury to the metal.

6. **Length.** The lengths shipped shall not average less than sixteen (16) feet on the whole order and not more than five per cent (5%) of the lengths shipped may consist of short pieces joined together, and no piece so joined may be less than five feet long, nor may more than one joint be made in any length.

7. **Protective Coating.*** After forming the joint and applying the rings, each pipe shall be thoroughly cleaned inside and outside from all

* See articles on Protective Coatings, pages 94 and 106. See index.

loose scale, dirt, rust, etc., and shall then be heated until perfectly dry. The pipes shall then be transferred to the dip bath before they become chilled, and shall remain in the dip sufficient time for the pipe and bath to reach practically the same temperature. The immersion in the dip bath shall be horizontal and the pipes shall be lifted out at sufficient angle to allow the surplus coating to drain off before it has time to harden. The bath shall be maintained at a practically constant temperature which shall not be less than the boiling point of water. The compound shall consist of a good quality of refined coal tar pitch free from water and the lighter oils, and of such uniform consistency that it will not chip off by blows or friction at 60 degrees Fahr., nor be liable to soften unduly so as to run when exposed to a reasonable amount of solar heat.

If any other compound is required, it must be clearly specified, otherwise the National Tube Company standard pipe dip will be applied.

8. **Galvanizing.** Where galvanizing is required, the finished pipe shall be cleaned free from scale by pickling in warm dilute sulphuric acid; the pipe shall then be washed in a bath of water; then immersed in an alkaline or neutral bath, then dried and immersed in molten zinc, being allowed to remain in the bath until it acquires the temperature of the zinc. No wiping or scraping device shall be used which will render the zinc coating thin. When cool, the clean galvanized pipe shall be coated as described in section 7, when specifically required.

9. **Loading and Shipping.** When loading for transport the pipe shall be handled in such manner that the least possible injury will be done to the coating, and after loading on cars, it must be well braced so as to avoid shifting while in transit.

The contractor shall at his expense and without extra charge, ship sufficient coating, ready mixed for application by brush, to repair the unavoidable abrasion that may occur to the coating while in transit.

10. **Measurement.** The pipe will be measured over-all length and so charged. Purchaser should use care that in ordering laid length required he considers the length of over-lap in joint shown by Fig. 26, page 84.

11. **Inspection.** The material and workmanship shall at all times during the course of manufacture be open for inspection by customer or by an inspector authorized to act in his behalf. All tests shall be made at the mill and the acceptance by customer or his authorized inspector shall be final and the makers' liability under this specification shall thereupon cease. The manufacturer shall furnish the inspector free of extra charge every reasonable facility required to witness the tests, and make the inspection called for under this specification, and shall give the inspector due notice as to when work on the order will begin.

SPECIFICATION FOR CONVERSE LOCK JOINT PIPE

1. **General Description of Pipe.** The pipe shall be made of uniformly good quality soft welding steel rolled from solid ingots. Sufficient crop shall be cut from the ends to insure sound material. The pipe shall be manufactured by what is known in the trade as the lap-weld process and each length shall be fitted with Converse Lock Joint.

2. **Design of Joint.** The Converse Lock Joint is made by means of a cast iron hub whose inner surface has an inwardly projecting ring at mid-length; on each side of this ring are two wedge-shaped pockets, diametrically opposite; near each mouth of the hub is a recess for lead. Close to each end of the pipe are two strong rivets, placed at such distance from the end that when the pipe is inserted into the hub and slightly rotated (see illustration page 84), the rivets engage the slopes of the wedge-shaped pockets and force the end of the pipe against the central ring of the hub. Lead is then poured into the recess provided for it and securely calked.

3. **Hubs.** The Converse Lock Joint Hub shall be cylindrical; shall be made of the best foundry iron and shall be cast to uniform patterns, strictly in conformity with diameters of the pipe. Converse Lock Joint Tees, Elbows and Crosses can be supplied when so ordered.

4. **Surface Inspection.** The pipe must be reasonably straight and free from blisters, cracks or other injurious defects. Liquor marks incidental to the manufacture of lap-welded pipe will not be considered as surface defects. The pipe shall not vary more than 1 per cent either way from the mean outside diameter specified. The pipe must not vary more than 5 per cent either way from weight as listed; any piece selected for test must be at least 18 feet long. Shorter lengths may be more than 5 per cent over weight, but must not be more than 5 per cent under weight.

5. **Strength of Material.** The steel used shall show the following physical properties on test pieces cut from finished pipe:

Tensile strength............	52 000 to 62 000 pounds per square inch.
Elastic limit................	Not less than 30 000 pounds per square inch.
Elongation in 8 inches.......	Not less than 18%.
Reduction in area...........	Not less than 50%.

6. **Internal Pressure Test.** Each piece of pipe shall be tested to a hydrostatic pressure not less than that shown in table, page 74, without showing any leak or injury to the metal.

7. **Length.** The lengths shipped shall not average less than sixteen (16) feet on the whole order and not more than five per cent (5%) of the lengths shipped may consist of short pieces joined together, and no piece so joined may be less than five feet (5′ 0″) long, nor may more than one joint be made in any length.

8. Protective Coating.* After forming the joint and applying the hubs, each pipe shall be thoroughly cleaned inside and outside from all loose scale, dirt, rust, etc., and shall then be heated until perfectly dry. The pipes shall then be transferred to the dip bath before they become chilled, and shall remain in the dip sufficient time for the pipe and bath to reach practically the same temperature. The immersion in the dip bath shall be horizontal and the pipes shall be lifted out at sufficient angle to allow the surplus coating to drain off before it has time to harden. The bath shall be maintained at a practically constant temperature which shall not be less than the boiling point of water. The compound shall consist of a good quality of refined coal tar pitch free from water and the lighter oils, and of such uniform consistency that it will not chip off by blows or friction at 60 degrees Fahr., nor be liable to soften unduly so as to run when exposed to a reasonable amount of solar heat.

If any other compound is required, it must be clearly specified, otherwise the National Tube Company standard pipe dip will be applied.

9. Galvanizing. Where galvanizing is required, the finished pipe shall be cleaned free from scale by pickling in warm dilute sulphuric acid; the pipe shall then be washed in a bath of water; then immersed in an alkaline or neutral bath, then dried and immersed in molten zinc, being allowed to remain in the bath until it acquires the temperature of the zinc. No wiping or scraping device shall be used which will render the zinc coating thin. When cool, the clean galvanized pipe shall be coated as described in section 8, when specifically required.

10. Loading and Shipping. One end of each length of Converse Joint pipe shall be securely leaded into a hub before shipment is made from the mill. When loading for transport, the pipe shall be handled

*** Note : National Coating.**

Where required we can furnish special covering of heavy fabric saturated with protective compound, which will be applied over the regular coating as described in paragraph 8. The process of applying this special coating being as follows:

The fabric shall be wound spirally around the pipe overlapping about one inch on each turn, and shall be thoroughly saturated with the hot compound before being applied to the pipe. The wrapping will be carried up to but not cover the joint.

Method of Protecting the Joints when Assembled in the Field:

After the joint has been completely assembled in the ditch, the part left unprotected should first be wiped free of dirt and moisture and then thickly coated with compound furnished for that purpose. After this a piece of fabric of sufficient width (wider than the hub) having length enough to encircle the hub a little more than twice is slashed near each edge with cuts running transversely about 2 inches apart. This strip of fabric is then saturated with compound and is then wound tightly over the hub, the slashes permitting it to fit closely thereto and also permitting the edges of the fabric to be drawn down against the pipe on each side of the hub. This wrapping of the hub should then be thoroughly covered with compound.

Compound and fabric used in protecting field joints will be furnished free of charge when National Coating is specified.

in such manner that the least possible injury will be done to the coating, and after loading on cars, it must be well braced so as to avoid shifting while in transit.

The contractor shall at his expense and without extra charge, ship sufficient coating, ready mixed for application by brush, to repair the unavoidable abrasion that may occur to the coating while in transit.

11. **Measurement.** The pipe will be measured over-all length and so charged. Purchaser should use care that in ordering laid length required, he considers the length of pipe inserted in the hub shown by Fig. 28, page 84.

12. **Inspection.** The material and workmanship shall at all times during the course of manufacture be open for inspection by customer or by an inspector authorized to act on his behalf. All tests shall be made at the mill and the acceptance by customer or his authorized inspector shall be final and the makers' liability under this specification shall thereupon cease. The manufacturer shall furnish the inspector free of extra charge every reasonable facility required to witness the tests, and make the inspection called for under this specification, and shall give the inspector due notice when work on the order will begin.

SPECIFICATION FOR PIPE FOR FLANGING AND BENDING

The pipe shall be lap-welded, made of Bessemer or Open Hearth Steel of the best welding quality, free from blisters, cracks or other injurious defects.

Inspection and Testing of Material

1. Each length of pipe is to be inspected separately for defects inside and outside, noting particularly the character of the cross section when cutting off crop ends.

2. A flattening test is to be made on each crop end with the weld near the side, crushing the end down to one-quarter the diameter of the pipe; it must not show cracks in the material or opening at the weld.

3. An internal hydrostatic test is to be made on each length of finished pipe, using the pressure customary in regular mill practice according to diameter and thickness specified.

4. The Chief Inspector will file a written report on each order tested showing the percentage of pieces which fail under each section of this specification; copy to be forwarded to the office of the General Superintendent.

SIGNAL PIPE

(Standard Specification approved by the Railway Signal Association, Oct., 1910.)

Pipe. 1. Pipe must be of soft steel, straight, tough and uniform in quality; free from cinder pockets, blisters, burns and other injurious flaws, must be hot galvanized inside and outside, unwiped.

2. The tensile strength, limit of elasticity and ductility shall be determined from a test piece cut from finished pipe.

3. The pipe shall have a tensile strength of not less than 52 000 pounds per square inch, and an elastic limit of not less than 30 000 pounds per square inch, and an elongation of not less than 18 per cent, in a measured length of eight inches. All pipe must stand a test of 600 pounds per square inch internal hydrostatic pressure without leak.

A piece of pipe one foot long will be selected at random and be subjected to a flattening test by hammering the piece until the opposite sides are within twice the thickness of the wall from each other; the piece shall show no cracks in the steel except at the weld.

4. The weight of one foot of one inch pipe before galvanizing should be 1.71 pounds, and in no case will pipe be accepted weighing less than 1.63 pounds per foot, weight of plug and coupling not included.

5. The outside diameter of pipe must conform to Briggs standard. Any pipe enough less than 1.31 inches in diameter to result in a flat thread will be rejected.

6. The manufacturer shall furnish all necessary facilities for making tests and the tests shall be made at the mill.

7. Inside diameter of all pipe must be large enough to receive a hardened steel plug of 63/64 inch diameter for a length of six inches.

8. Not more than one per cent of pipe less than fifteen feet long will be accepted, lengths of seventeen feet and over preferred.

9. The ends of pipe must be cut square and drilled for two 1/4-inch rivets on one end only; first rivet hole shall be drilled two inches from the end and the second two inches from this and at right angles to it.

10. Each length of pipe shall have a thread 1 1/8 inches long, 3/8-inch total taper per foot, 11 1/2 "V" threads to the inch, slightly rounded top and bottom; the threaded portion of the pipe shall be of such diameter as to permit the coupling to be screwed on five turns by hand, with permissible variation of one turn either way.

Couplings. Couplings must be galvanized, to be 2 1/4 inches long and 1 3/4 inches outside diameter, of wrought iron, free from defects, faced at ends and tapped straight through, pitch diameter of thread to be 1.26 inches, variation not more than .003 of an inch, so as to fit pipe as per section 10 above.

Plugs. Plugs must be merchant bar steel, ten inches long, 31–32 inch in diameter, drilled for four 1/4-inch rivets with drill .256; spacing to be one inch, two inches, four inches, two inches, one inch, the outside

holes to be in one plane and the inside holes to be in a plane at right angles to the outside holes.

Rivets. Rivets must be galvanized, must be of soft iron or steel ¼ inch in diameter, 1$^{11}/_{16}$ inches long.

1-inch Signal Pipe

(For specification see page 96.)

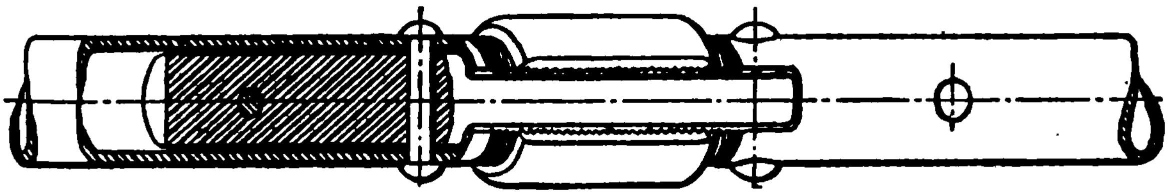


Fig. 43. Joint Assembled

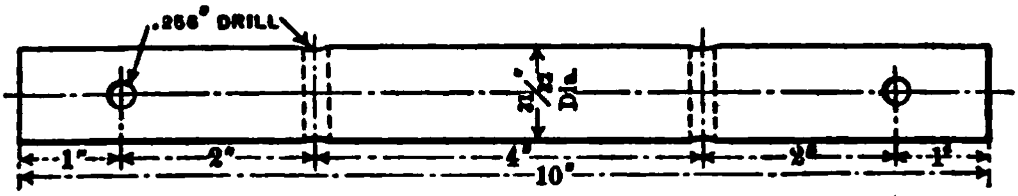


Fig. 44. Plug, Merchant Bar Steel

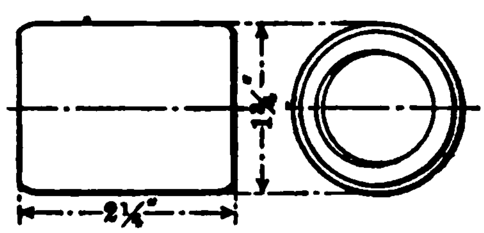


Fig. 45. Coupling, Wrought Iron, Galvanized

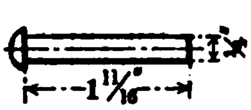


Fig. 46. Rivet, Soft Iron or Steel, Galvanized

SPECIFICATIONS FOR SPECIAL AMMONIA PIPE

1. **Material.** Welded pipe is to be made of uniformly good quality soft weldable steel rolled from solid ingots. Sufficient crop shall be cut from the ends to insure sound material, and the steel shall be given the most approved treatment in heating and rolling.

2. **Process of Manufacture.** All pipe 2 inch and larger to be lap-welded; smaller sizes to be butt-welded and redrawn from a larger size.

3. **Surface Inspection.** Pipe must be reasonably straight and free from blisters, cracks or other injurious defects. Liquor marks incidental to the manufacture of lap-welded pipe will not be considered as surface defects. The pipe shall not vary more than one per cent either way from being perfectly round or true to standard outside diameter, except on the small sizes, where a variation of 1/64 of an inch will be permitted. The pipe must not vary more than 5 per cent either way from the weight specified.

4. **Threading and Reaming.** Where required pipe must have a good Briggs Standard thread, which will make a tight joint when tested by hydraulic pressure at the mill (Paragraph 5). The thread must not vary more than one and one-half turns either way when tested with a Pratt & Whitney Briggs Standard gage. All burrs at the ends are to be removed.

5. **Internal Pressure Test.** Each length of National Special Ammonia Pipe when lap-welded shall be tested at the mill to 2000 pounds hydrostatic pressure; when butt-welded and redrawn, the test pressure shall be 1500 pounds.

6. **Testing of Material.** The steel from which the pipe is made must show the following physical properties:

Pipe Steel

Tensile strength	52 000 to 62 000 pounds per square inch.
Elastic limit	Not less than 30 000 pounds per square inch.
Elongation in 8 inches	Not less than 20%.
Reduction in area	Not less than 50%.

A test piece cut lengthwise from the pipe and filed smooth on the edges shall bend through 180 degrees with an inner diameter at the bend equal to the thickness of the material, without fracture.

7. **Couplings.** The material to be sound and free from injurious defects. Threads must be clean cut, tapered same as pipe, and of such pitch diameter as will make a tight joint. The ends must be countersunk.

8. **Thread Protection.** Solid tapped rings or split couplings will be provided as thread protectors on pipe 2 inches and larger. Thread protection will be provided for smaller sizes when specifically called for on order.

9. All tests shall be made at the mill.

SPECIFICATIONS FOR LAP-WELDED LOCOMOTIVE BOILER TUBES AND SAFE ENDS

Material

Material must be good welding quality Basic Open Hearth Steel, Spellerized.

Chemical Composition.

Phosphorus must not be over.............................. .04%
Sulphur must not be over.............................. .05%
Carbon must not be over.............................. .12%
Manganese.............................. .30 to .45%

Sample for chemical analysis to be taken by drilling at several points around the circumference of the tube.

Dimensions, Weights and Test Pressures

Outside diameter	Decimal thickness	Nearest B.W.G.	Weight per foot, pounds	Test pressure, pounds
1¾ inches	.095	13	1.68	900
	.110	12	1.93	900
	.125	11	2.17	1000
	.135	10	2.33	1000
2 inches	.095	13	1.93	900
	.110	12	2.22	900
	.125	11	2.50	1000
	.135	10	2.69	1000
2¼ inches	.095	13	2.19	900
	.110	12	2.51	900
	.125	11	2.84	1000
	.135	10	3.05	1000
2½ inches	.110	12	2.81	800
	.125	11	3.17	800
	.135	10	3.41	900

The permissible variation in weight is 5% above or 5% below that given above.

Inspection

(*a*) Tubes shall have a reasonably smooth surface, free from injurious pits, laminations, cracks, blisters or imperfect welds; they shall also be free from kinks, bends and buckles, signs of unequal contraction in cooling or injury during manufacture.

(*b*) The thickness of the wall shall not vary more than 10% above or 10 % below the gage specified.

(*c*) Tubes shall be round within .02 inch.

(*d*) The mean outside diameter shall not vary more than .015 inch from the size ordered.

(*e*) Tubes shall not be less than the length ordered, nor more than .125 inch longer.

Physical Tests

A combination of vertical and horizontal flattening and flange test must be made on the crop end cut from each end of every tube, the flange being about ⅝ inch wide. If required, standard ring, expanding and flattening tests will also be made (see N. T. Co.'s specification for seamless tubes page 102), but it is believed that in view of the above combination test on each tube, for which a special machine has been designed, further testing is unnecessary.

Internal Pressure Test. Each tube shall be subjected by the manufacturer to an internal hydrostatic pressure for the respective size and gage as given in above table of Dimensions, Weights and Test Pressures.

General Requirements

In addition to the above tests, tubes, when inserted in the boiler, must stand expanding and beading without showing crack or flaw, or opening at the weld. Those which fail in this way will be returned to the manufacturer.

Each tube must be plainly stenciled "Spellerized Steel Tested to . . . Pounds" (according to the respective size and gage as shown in above table) and tubes shall be so invoiced.

All tests to be made at place of manufacture under the supervision of the Railroad's Inspector or his deputy.

SPECIFICATIONS FOR LAP-WELDED AND SEAMLESS STEEL BOILER TUBES FOR MERCHANT AND MARINE SERVICE

Material

Material must be good quality soft steel rolled from solid ingots. Sufficient crop shall be cut from the ends to insure sound material.

The permissible variation in weight is 5 per cent above or 5 per cent below the calculated weight.

Inspection

(a) Tubes shall have a reasonably smooth surface, free from injurious pits, laminations, cracks, blisters or imperfect welds; they shall also be free from kinks, bends and buckles, signs of unequal contraction in cooling or injury during manufacture.

(b) The thickness of the wall shall not vary more than 10 per cent above or below the gage specified, except at the weld where .015 inch extra thickness will be allowed.

(c) Tubes shall not vary more than one-half (½) of one per cent either way from being round or true to the mean outside diameter, except in the smaller sizes where a variation of .015 of an inch will be accepted.

(d) Tubes shall not be shorter than the length ordered, nor more than .125 inch longer.

Physical Tests

Flattening Test. A section three (3) inches long shall stand hammering flat cold until the inside walls are within three times the thickness of the material without cracking at the bend or elsewhere. In

case of Lap-welded tubes for Marine work, the bend at one side shall be made in the weld.

Flanging Test. For Marine purposes on Lap-welded tubes four (4) inches and smaller and on all sizes of seamless tubes, a flange three-eighths (3/8) of an inch wide shall be turned over at right angles to the body of the tube without showing crack or opening at the weld.

Internal Pressure Test. Each Lap-welded tube shall be subjected by the manufacturer to an internal hydrostatic pressure for the respective size and gage as given in table, page 72. And all Seamless Boiler Tubes are tested to 1000 pounds.

General Requirements

In addition to the above tests, each tube when inserted in the boiler must stand expanding and flanging where required without cracking or opening at the weld. Tubes which fail in this way may be returned to the manufacturer.

A certificate of test shall be furnished the purchaser of each lot of tubes, for Marine service, describing the kind of material from which the tubes were made, and that the tubes have been tested and have met all the requirements prescribed by the Board of Supervising Inspectors, Department of Commerce and Labor, Steamboat Inspection Service.

All tests to be made at place of manufacture.

SPECIFICATIONS FOR SEAMLESS COLD DRAWN LOCOMOTIVE BOILER TUBES AND SAFE ENDS

Material

Tubes to be made of our standard soft Basic Open Hearth Steel.

Chemical Analysis. Sulphur and phosphorus not to exceed .04%. Sample for chemical analysis to be taken by drilling several points around the circumference of the tubes.

Dimensions and Weights

Outside diameter	Decimal thickness	Nearest B.W.G.	Weight per foot, pounds
1¾ inches	.095	13	1.68
	.110	12	1.93
	.125	11	2.17
	.135	10	2.33
2 inches	.095	13	1.93
	.110	12	2.22
	.125	11	2.50
	.135	10	2.69
2¼ inches	.095	13	2.19
	.110	12	2.51
	.125	11	2.84
	.135	10	3.05
2½ inches	.110	12	2.81
	.125	11	3.17
	.135	10	3.41

Inspection

(*a*) Tubes shall have a smooth surface, free from injurious pits, checks, cracks or laminations. Tubes shall be free from bends, kinks, buckles or other defects which would shorten their life or otherwise limit their usefulness.

(*b*) The thickness of the wall shall not vary more than 10% above or 10% below the gage specified.

(*c*) Tubes shall be round within .02 inch.

(*d*) The mean outside diameter shall not vary more than .010 inch from the size ordered.

(*e*) Tubes shall not be less than the length ordered, nor more than .125 inch longer.

Physical Tests

1. *Ring Tests.* Coupons 1 inch long cut from a tube shall stand hammering down vertically into the shape of a ring without showing cracks or flaws when crushed flat.

2. *Expanding Tests.* Sections of tubes 8 inches long, with or without heating, shall be placed in a vertical position and a smooth tapered steel pin forced into the end of the tube. Under this test the tube shall expand to 1⅛ times its original diameter without splitting or cracking. The steel pin used for this test shall be of tool steel and have a taper of 1½ inches per foot of length. When this test is made hot, the tube shall be heated to a bright cherry red in daylight, and the pin at a blue heat forced in as described.

3. *Flange Test.* For tubes 1¾ inches diameter and larger, coupons 8 inches long, cut from the tube, shall have a flange ⅜ inch wide turned over at right angles to the body of the tube without showing crack or flaw. For tubes less than 1¾ inches diameter, the width of flange shall be ⅛ the diameter of the tube. All the work is to be done cold.

4. *Flattening Test.* A section 4 inches long shall stand hammering flat cold until the inside walls are in contact, without cracking at the edges or elsewhere.

Two tubes to be tested as required in preceding paragraphs under "Physical Tests" in each lot of 250 tubes or less. If only one of the tubes so tested fails, that tube will be rejected, and the Inspector will take two more tubes from the same lot and subject both to the same tests as the one that failed; both of these tubes must be found satisfactory in order that the lot may be passed.

5. *Internal Pressure Test.* Each tube must be subjected by the manufacturer to an internal hydrostatic pressure of 1000 pounds per square inch.

General Requirements

In addition to above tests, tubes when inserted into boilers must stand expanding and beading without showing crack or flaw.

Each tube must be plainly stenciled "Shelby Seamless Cold Drawn Tested to 1000 Pounds" and tubes must be so invoiced. All tests to be made at place of manufacture under the supervision of the Railroad Inspector or his deputy.

SPECIFICATIONS FOR SHELBY SEAMLESS COLD DRAWN STEEL TUBES FOR CREAM SEPARATOR BOWLS AND SIMILAR ARTICLES

Material

Tubes for separator bowls shall be manufactured of our Standard, Class "A" Basic Open Hearth Steel.

Allowances for Machining

CASE 1. The Material Chucked True on the Outside:

To the finished outside diameter add 1/16 inch for the outside diameter of the unfinished bowl.

From the finished inside diameter subtract .222 times the finished wall thickness plus .051 inch for the inside diameter of the unfinished bowl.

CASE 2. The Material Chucked True on the Inside:

To the finished outside diameter add .222 times the finished wall thickness plus .051 inch for the outside diameter of the unfinished bowl.

From the finished inside diameter subtract 1/16 inch for the inside diameter of the unfinished bowl.

CASE 3. Method of Chucking Unknown:

Add to the finished outside diameter and subtract from the finished inside diameter one-fourth (1/4) of the finished wall thickness plus .050 inch for the outside and inside diameters respectively of the unfinished bowl.

The proper allowances for finished walls from 1/8 inch to 1/2 inch, by 1/32 inch steps, are given in table, page 104.

Inspection

(*a*) *Surface*. The surface inside and outside must be free from all defects that are more than .010 inch in depth, or the extent of which is not clearly discernible.

(*b*) *Limits of Size*. The outside diameter shall not vary more than from full size to .01 inch over, for tubes 2 inches and over in diameter, nor more than from full size to .005 inch over, for tubes under 2 inches in diameter. The inside diameter shall not vary more than from full size to .01 inch under full size. The wall shall not vary more than 10%, above or below, of the specified thickness of wall of the required tube.

(*c*) *Straightness*. Tubes for separator bowls, when cut to the bowl length by the mill, shall not be more than $\frac{1}{64}$ inch from straight when measured on the cut bowl.

(*d*) *Length*. Bowls cut to length shall not vary in length more than from full length specified to 1/8 inch over.

Shipment

Tubes for separator bowls, when shipped in long lengths, shall be oiled to prevent corrosion. Each tube shall be stenciled with the

consignee's name and address and the manufacturer's identification mark, unless tubes are bundled, in which case one tube of each bundle shall be so stenciled. When bowls are cut to length by the manufacturer they shall be boxed for shipment without oiling.

Table of Allowances for Machining Shelby Seamless Steel Tubing for Tubes 10 inches and Less in Length

Finished wall	Case 1		Case 2		Case 3	
	Increase finished outside diameter by	Decrease finished inside diameter by	Increase finished outside diameter by	Decrease finished inside diameter by	Increase finished outside diameter by	Decrease finished inside diameter by
Inch	Inch	Inch	Inch	Inch	Inch	Inch
1/8	1/16	.079	.079	1/16	.081	.081
5/32	1/16	.086	.086	1/16	.089	.089
3/16	1/16	.093	.093	1/16	.097	.097
7/32	1/16	.100	.100	1/16	.105	.105
1/4	1/16	.107	.107	1/16	.113	.113
9/32	1/16	.114	.114	1/16	.120	.120
5/16	1/16	.121	.121	1/16	.128	.128
11/32	1/16	.128	.128	1/16	.136	.136
3/8	1/16	.135	.135	1/16	.144	.144
13/32	1/16	.142	.142	1/16	.152	.152
7/16	1/16	.148	.148	1/16	.159	.159
15/32	1/16	.155	.155	1/16	.167	.167
1/2	1/16	.162	.162	1/16	.175	.175

Note. For finished wall sizes expressed as decimals, use the tabular allowance for the nearest 1/32.

Case 1. — The material chucked true on outside.
Case 2. — The material chucked true on inside.
Case 3. — Method of chucking unknown.

SPECIFICATIONS FOR SHELBY SEAMLESS COLD DRAWN STEEL TUBES FOR DIAMOND DRILL RODS

Material

Tubes for drill rods shall be manufactured from Standard, Class "A" Basic Open Hearth Steel.

Upsets

The heating for upsetting the ends of tubes for drill rods shall be conducted in such a manner that the surface of the tube shall not be injuriously scaled. The heated portion must not extend beyond the portion being upset, farther than is necessary to insure proper working of the metal. The heated portion shall in no case extend beyond the dies

gripping the tube during the operation of upsetting. The upset portion shall be straight and in line with the tube. The diameter and wall of the tube beyond the upset portion shall not be reduced by the upsetting operation.

Inspection

(a) *Surface.* The outside and inside surface of tubes for drill rods shall be smooth and free from scale. Slight pits or scratches are not objectionable unless they may form starting points for corrosion.

(b) *Straightness.* Tubes for drill rods shall be straightened on the rotary straightening machine and shall be straight within 3/32 inch; i.e., they shall be capable of being passed through a perfectly straight tube whose inside diameter is 3/32 inch greater than the outside diameter of the drill rod.

(c) *Limits of Size.* The outside diameter of the tube shall not vary more than from full size to .010 inch over, for tubes 1½ inch and over in diameter, nor more than from full size to .005 inch over, for tubes under 1½ inch in diameter. On the upset portions the limits shall be from full size to .030 inch over. The wall of the tube shall not vary more than 10% of the specified thickness above and below. The inside diameter of the upset shall in no case be greater than that specified, but may be ⅛ inch less.

(d) *Limits of Length.* The length after upsetting shall not be less than that specified nor more than 3/16 inch greater.

Shipment

Drill Rods shall be oiled before shipment, as a protection against rust. Each tube shall be stenciled with consignee's name and address and manufacturer's identification mark, unless tubes are bundled, in which case one tube of each bundle shall be so stenciled.

SPECIFICATIONS FOR SHELBY SEAMLESS COLD DRAWN STEEL TUBES FOR HOSE POLES AND HOSE MOLDS

Material

Tubes for hose poles and hose molds shall be manufactured from Class "A" Basic Open Hearth Steel.

Inspection

(a) *Surface.* The outside surface of tubes for hose *poles* shall be as smooth as possible, free from all pits and scale marks, seams, scratches, etc. The inside does not require inspection.

Tubes which are to be used for hose *molds* shall have an inside surface of the same character as the outside surface of hose poles.

(b) *Straightness.* Tubes for hose poles or hose molds shall be as straight as possible, free from short bends and kinks.

(c) *Limits of Size.* The outside diameter of tubes for hose poles or hose molds shall not vary more than from full size to .010 inch over,

for tubes 1½ inch and over in diameter, nor more than from full size to .005 inch over, for tubes less than 1½ inch in diameter; the inside diameter shall not vary more than from full size to .005 inch under; the wall of the tube shall not vary more than 10% of the specified wall thickness.

Tubes for hose poles that are to be coupled together to form longer lengths than can be obtained with a single tube, will require machining to insure proper register of the connected tubes.

(*d*) *Limits of Length.* The length of tubes for hose poles or hose molds shall not be less than the length specified, nor more than 3/16 inch greater.

Shipment

Hose poles and hose molds shall be oiled and boxed for shipment, unless otherwise specified.

PROTECTIVE COATINGS

In some cases it is impossible to use a protective coating on tubes, as for example in boilers or condenser tubes. In many other cases the metal is left unprotected on account of the difficulty of applying adequate protection, or the cost. In such cases the life of the metal depends on the care and experience used in its manufacture. Under the section on "Corrosion," page 12, the theory and conditions which cause corrosion, and reasons for abandoning the use of puddled iron in favor of the special grade of soft steel which has been developed exclusively for the manufacture of pipe were given. A step of such importance to the future of the business amounted almost to a turning point in the industry, but was accomplished gradually during a period of fifteen years of experimenting, the percentage production of steel pipe in our mills being increased year by year until it constituted practically our entire output two years ago. The question of the durability of the material under natural corrosion was given years of study, both in the laboratory and field, and the manufacture of wrought iron was not abandoned until we had ample proof from service tests covering years of exposure under many conditions that the steel was as durable as the best puddled iron. Those having any doubt on this question are invited to take up the matter with our Metallurgical Department, where a considerable amount of evidence has been accumulated.

Under some conditions, such as hot-water heating systems, where the water is not changed, or in refrigerating systems where ammonia is in contact with the metal, corrosion is so slow as to be negligible. But wherever there is any considerable amount of exposure to corrosive conditions, suitable protective coatings should be applied, when possible.

Surrounding conditions have so much to do with the proper coating to be used that we need only outline the matter here, referring those particularly interested to the publications of the American Paint Manufacturers' Association, and the Proceedings of the American Society for

Testing Materials, who have done a great deal to put the subject on a scientific basis, and, by field tests conducted under impartial conditions, have in some measure been able to lay down certain principles on which suitable protective coatings may be selected.

For the protection of pipe we either galvanize, dip hot in bituminous compound, which may afterwards be covered with strong fabric saturated with protective compound, or paint as specified.

Galvanizing is applied by dipping the clean hot pipe in a bath of pure zinc kept somewhat above the melting point. The pipe is removed from the bath covered with zinc inside and outside, and cooled *without* wiping.

Bituminous Coating made of the proper consistency for the average temperature to which the pipe is subjected is applied by dipping, followed by baking. (See also paragraph 7 — page 91.)

National Coating. By a second operation this bituminous compound which has been baked on the pipe to an enamel like surface is wrapped with a strip of fabric thoroughly saturated with hot compound.

Immediately after being saturated with the compound the fabric is stretched tightly over the surface overlapping about one inch on each turn, covering and firmly adhering to the body coat. Two or three thicknesses may be applied where desired to meet special conditions.

Paint will be applied according to specification from customer.

MATHESON JOINT PIPE *

Matheson Joint is a pipe joint of the bell and spigot type and is very similar in appearance to a cast iron pipe joint. There are no loose parts of any kind, the joint being made directly on the pipe. The pipe used in connection with this joint ranges in size from 2 inches to 30 inches outside diameter and the standard thicknesses are much lighter than any other pipe, but in order to withstand varying pressures the pipe is made of different thicknesses. For list of sizes, thicknesses, weights and dimensions see table, page 42. For test pressures see table, page 73.

The Joint is made by belling out or expanding one end of the pipe in such a manner as to permit the bell end to slip over the plain or spigot end of the next length of pipe leaving enough space between the two for the lead which is to make the joint. After the end of the pipe has been shaped a wrought band is shrunk on the outside of the bell to reinforce it at this point and to keep it in shape to withstand the calking of the lead. The spigot end of the pipe has a recess turned in it which prevents the lead from blowing out or the pipe from pulling out.

The Particular Advantages of this joint are that it is so designed as to give a continuous, straight, smooth surface inside which reduces the friction losses to a minimum.

The lead required per joint is less than for other lead joint pipes of the same diameter.

* **For illustration of joint see page 84.**

This style of joint permits variations in alignment and grade which are often necessary. This feature alone frequently avoids special fittings and pipe bends.

For very high pressures the joint is reinforced with a clamp and a rubber packing which increases its efficiency so that it becomes as strong as the body of the pipe. After the joint has been finished each piece is tested to a hydrostatic pressure of 450 to 700 pounds, depending on the size and thickness.

The average length of this pipe is 18 feet or about 300 joints per mile.

The pipe is furnished black (no coating), asphalted, galvanized and then dipped in asphalt, or with our special National coating, which consists in dipping the pipe and then wrapping it with a fabric that is saturated with a special compound, laid on spirally with a lap of about 1 inch. This wrap coating forms the best protection against underground corrosion and electrolysis that is known at the present time. The thickness of the National coating (applied once) is about 3/64 of an inch and may be made to any desired thickness by additional coatings or wrappings while the ordinary dipped coating or paint is about 1/100 of an inch thick.

CONVERSE LOCK JOINT*

Converse Lock Joint is a lead joint used in connection with wrought pipe. The pipe used with this joint ranges in size from 2 inches to 30 inches outside diameter, and in order to withstand varying pressures the pipe is made of different thicknesses. For list of sizes, thicknesses, weights and dimensions see table, page 43. For test pressures see table, page 74.

The joint consists of a cylindrical cast iron hub or sleeve whose length varies with its diameter. It is provided with an annular ring or projection midway in its length, so as to form on either side of its center an annular shoulder against which the ends of the pipe section butt or bear. The ring is made the same height as the thickness of the metal in the pipe, so as to give a straight, continuous, smooth surface inside which reduces the friction losses to a minimum. The hub extends out a sufficient distance on either side of the central ring to support the pipe. Between the end of the hub and the central ring is an annular recess for the reception of the lead. This recess being formed inwardly and being of a larger diameter at the base than at the mouth, holds the lead securely in place and prevents its displacement. Inside the hub or sleeve, on each side of the central ring, are two "T" shaped pockets, diametrically opposite. Close to each end of the pipe are two rivets, placed at such distance from the end, that when the pipe is inserted into the hub and slightly rotated, the rivets engage the slopes of the wedge-shaped pockets and force the end of the pipe against the central ring of the hub, locking it in position ready for the lead which is to make the joint. After the lead is poured the joint is thoroughly calked.

* For illustration of joint see page 84.

Converse Joint Pipe is always shipped with a hub leaded on one end of each pipe and the other, or spigot end, is provided with rivets for slipping into the hub end of the next length of pipe.

The lead required for the field joint is slightly in excess of that required for Matheson Joint Pipe, but is considerably less than other lead joint pipe of the same diameter. This joint like the Matheson Joint permits variations in alignment and grade which are often necessary and this feature alone frequently avoids special fittings and pipe bends.

For very high pressures the joint is reinforced with a clamp and rubber packing which increases its efficiency considerably. Each piece of pipe is tested to a hydrostatic pressure of 450 to 700 pounds, depending on the size and thickness.

The average length of this pipe is 18 feet or about 300 joints per mile.

The pipe is furnished black (no coating), asphalted, galvanized and then dipped in asphalt, or with our special National Coating which consists in dipping the pipe and then wrapping it with a fabric that is saturated with a special compound, laid on spirally with a lap of about 1 inch. This wrap coating forms the best protection against underground corrosion and electrolysis that is known at the present time. The thickness of the National Coating (applied once) is about 3/64 of an inch and may be made to any desired thickness by additional coating or wrappings.

TUBULAR ELECTRIC LINE POLES

The National Tube Company makes tubular electric line poles of steel pipe. These poles have great durability, stiffness, and strength. Steel poles are becoming more generally used for carrying the wires for the overhead construction on electric railway, telephone, telegraph, and transmission lines.

Customary Sizes. For railway work the poles most used are 30 feet long, and are composed of 7-inch, 6-inch, and 5-inch pipes. These are used for both center-pole and span-wire construction. Anchor poles are usually of 8-inch, 7-inch, and 6-inch pipes, although they are frequently made of larger sizes, often being of 10-inch, 9-inch, and 8-inch pipes. Poles 28 and 35 feet long are used to a large extent. Such lengths as 29, 31, and 32 feet are less common.

The British Standard tramway pole is 31 feet long; their standard permits no other length. A large assortment of peculiar lengths are used, some of which are 29 feet 6 inches, others vary one or two inches from the usual lengths, and at times the length is specified to fractional inches, even to 1/16 inch. The last is a practice which seems unwise, because the practical operation of assembling introduces variations of 1/4 inch or 1/2 inch not infrequently. However, all such peculiar and difficult requirements, that necessarily increase cost, relate to a very small percentage of the steel poles made.

Lengths. The length of poles appears to depend mostly upon the clearance required below the wires, in order to avoid injury to the wires

or injury from chance contact with those carrying high-tension lines. The length is also affected, to the extent of several feet, by the nature of ground in which planted and the depth of the frost line. The depth of planting above the frost line appears to give little aid in holding the pole, if indeed such depth does not tend to disturb the foundation of that portion below the frost line.

Telegraph Poles. These considerations make it impossible to give any general statements as to the lengths of poles for telephone, telegraph, or transmission lines. In some instances entire lines are carried at great height, as if the effort were to avoid chance contact. Such height may be required when the lines are on public highways or at road crossings. There has appeared, during recent years, a tendency to place the lines at lower elevation and only to raise them where the line crosses roads or public property. This seems especially true of the high-voltage lines, where there appears a strong tendency to have a private right-of-way strip, even fenced in, and the wires carried low, except at crossings. The claim has been made that it is cheaper to use very high poles, long spans, and great sags, but actual installations appear to tend towards the opposite construction.

Pages 120 to 157, give N. T. Co.'s table of standard poles. Sufficient variety of lengths, sizes, diameters, and sections are given to meet nearly all requirements of practice.

Section Lengths. Lengths of sections given in the tables have been selected so as to employ the regular mill-furnace lengths, without producing unnecessary scrap, and at the same time produce poles of light weight in relation to their strength.

The section lengths given, conform closely to those that are usually employed. These lengths should be specified, except when the practical requirements justify the increased cost.

The lengths of the sections of a pole have but little effect upon its strength, stiffness, or weight. For example: the table shows that a pole 30 feet long of 7-inch, 6-inch, and 5-inch pipe does not vary 3 per cent in weight for any of the various sections listed, whether of two pieces or three pieces, — the strength of all are alike, — and the deflection varies less than 4 per cent. In contrast, notice the great change produced by increasing the butt section to extra-strong pipe. The strength is increased about 50 per cent, the weight about 40 per cent, and the deflection decreased about 30 per cent. However, comparison of the various sets of section lengths shows that as long as the size and thickness of pipe remains unchanged, the strength, stiffness, and weight do not change by more than approximately 6 per cent. Other lengths of pole or sizes of pipe give slightly different results, as will be seen with a pole 30 feet long having 4-inch extra-strong butt section, and upper sections of standard pipe, or a pole 35 feet long of 5-inch extra-strong butt and upper sections standard. This is due to the weakness of the inserted pipe at the point of emergence from first joint above ground; however, this is not exhibited by poles of large diameter on either of above lengths. It is thus evident that the weight, strength, and stiffness of any pole are

but slightly affected by the lengths of the individual sections, provided the butt section is not made too short, considering the strengths of the upper sections.

Odd Sizes. Odd sizes, thicknesses, and weights mean special production, delay, and increased cost, therefore they should always be avoided, because such pipe has always to be made to order.

Use of Standard Pipe. Where it is not practical to use poles made up of standard or extra-strong pipe, it is advisable to use only the sizes and weights given in one of the standard lists of tubular goods given on pages 22-44. These have been collected into the table given on pages 58-65, and arranged by ascending sequence in diameter and weight. In this table the properties of pipe are also given, to enable their ready selection for needs of poles.

Jointing Special Sizes. Considerations of strength, stiffness, etc., at times suggest the advisability of such combinations as 4½ inch in 5-inch pipe, but these necessitate the assembling in a machine capable of forcing the smaller into the larger pipe. A forcing machine of this kind is expensive to change, and such joints should be used only where it will be possible to order large numbers of identical poles, unless the use warrants paying the extra assembling cost incurred where only a few are made at one time. On short orders (only a few poles), it is better to use such sizes and thicknesses as will allow the insertion of the smaller pipe freely by hand, — say at least ¼ inch difference in diameter between the outside diameter of the inserted pipe and the inside diameter of the larger pipe. This difference should never be less than 3/16 inch unless the quantity justifies the use of the forcing equipment, — say 1000 or more identical poles, all to be made and shipped at one time. In the case of such orders, it is desirable (though not necessary) to have the outside diameter of the inserted pipe a little larger than the inside diameter of the outside pipe.

Special Joint Reduction. Considerations of strength, stiffness, and a great limit of least thickness, sometimes leads to the choice of sizes of pipe that entail great reductions at the joints, viz., poles of 11-inch, 9-inch, 7-inch, and 4½-inch pipes. These require heavy swaging before assembling the poles. After the poles are assembled there is great risk of injury to the smaller sections when handling in transit or erection. It is frequently possible to obtain equal, or even a little greater strength, by the use of larger and thinner pipes for the upper sections, and to do this without increasing the total weight appreciably.

Material Used. The material of which these poles are made is usually known as "Soft Mild Steel." Its ultimate strength will average not less than 50 000 pounds per square inch, and its elastic limit — or yield point — not less than 30 000 pounds per square inch. For average values and composition, see pages 9–10. It is not considered good engineering to apply loads that impose stresses in the material

that are above the yield point. For this reason the tables give the load that will produce a stress about 10 per cent below the yield point, viz., 27 000, which is 90 per cent of 30 000. Although the deflection is usually closely proportional to the load up to this limit, it is considered proper to limit the deflection tests to loads that do not produce a fiber stress exceeding two-thirds of the former figure. The deflection tests are limited to loads that produce about 18 000 pounds per square inch fiber stress. The stiffness of poles depends upon the modulus of elasticity of the material. This physical constant is found to average about 29 000 000 for the steel used for poles, and on first loading, to vary to about the same extent as reported for other iron and steel by authorities as Lanza and others.

The deflections given are not based, however, on this figure directly, but are based on the greatest deflections found when testing poles that appear free from defects. The tabular deflection figures thus give the limit of deflections that poles will not exceed when tested as indicated. The average deflection will always be less than the tabulated deflection. These tabulated deflection figures have been adjusted to compensate for the ordinary irregularities of size, thickness, composition, and physical properties that are inseparable from the pipe-making processes.

Deflection Limits. Many specifications have been drawn up requiring poles of widely different lengths and diameters, all to stand the same deflection; this figure is commonly 6 inches. By reference to the tables it will be seen that a pole 22 feet long of 13-inch and 12-inch pipe should not be deflected more than about 1 inch, and that a pole 39 feet long of 4-inch, 3-inch, and 2½-inch pipe should be deflected about 18 inches when testing for deflection. It is thus evident that a constant figure like 6 inches for deflection may be six times more than, or only one-third of the amount that it ought to be. By reference to the tables it will be seen that a deflection of 6 inches is about the suitable figure for a pole 31 feet long of 6-inch, 5-inch, and 4-inch pipe. It is noteworthy that this length pole is the British Standard. Some framers of specifications have attempted to overcome the difficulty by reducing the limit deflection to 3 inches and some to 1½ inches. Against such it is proper to urge that 1½ inches would not strain a pole 39 feet long of 4-inch, 3-inch, and 2½-inch pipe sufficiently for the test to give any indication of the quality of the pole. It is more rational to use such load as will produce about a constant stress in the material and then fix the deflection limit to correspond. This has been done in the standard tables.

Set Limits. Poles are suitable for a certain maximum load that may be applied without producing appreciable permanent distortion; that is, poles which will stand being bent, and not remain permanently bent when the load is removed. The load that may be applied should not produce a fiber stress above the "yield point," — say not over 90 per cent of that for safety. Therefore, say not over 27 000 pounds per square inch. Such loads are listed for every pole in the table in column of maximum loads (P). After applying such loads there usually

remains a small fraction as permanent deflection (or set, as it is generally called). Some specifications have limited this to a constant figure, such as one inch or one-half inch, but this constant figure is as inappropriate for set as a constant figure is inappropriate for deflection. An able writer on elasticity of materials has said, in equivalent, that bars of ductile metal, as obtained from the manufacturers, on first application of any load within the elastic limit show a total elongation, but, on removal of load, retain in the form of set a portion of the elongation. Thus the elastic elongation is that portion which is immediately recoverable. However, on repeated applications of the same load, the metal arrives at a state where it acts as though perfectly elastic, provided the load does not exceed the initial load. Tests have shown that this set on first loading seldom exceeds 10 per cent of the distortion produced by that load. The practical difficulties of making these tests and measures impose a limit of such measures, which for commercial testing of poles is usually agreed on as ½ inch of permanent set. Thus a pole, which is deflected 5 inches on test, should not show a permanent set exceeding ½ inch, but a pole that is deflected 15 inches on test may show a set of 1.5 inches without exceeding rational bounds.

Deflection Versus Weight. By comparing the deflections tabulated, it will be seen that a pole of large diameter and thinner pipe is slightly stiffer and lighter than one of less diameter and greater thickness. Compare poles No. 7622 and 7651. The strength is say 9 per cent less, while the stiffness is increased a per cent or so, but there is a saving in weight of about 23 per cent. The rate of increase of strength and stiffness is, perhaps, more easily seen by referring to table of pipes on pages 58–65, and comparing the constants in columns Q and I, which are proportional to strength and stiffness respectively; 9-inch Standard pipe is about as stiff as an 8-inch extra-strong pipe, is only a few per cent less in strength, but it is about 22 per cent lighter than the 8-inch extra-strong. In general it will be seen that both strength and stiffness increase more rapidly than the weight as the diameter increases. On the other hand, for one diameter the weight increases more rapidly than the strength or stiffness, as the thickness is changed. This points to the advisability of always using as large a diameter as possible.

Dog Guards. The argument has been advanced against the use of large diameters and thin pipes that they present greater surface and less thickness where corrosion is greatest. The deterioration of poles, of all materials, occurs most rapidly at or near the surface of the ground. In order to prolong the life of poles it is necessary to protect this portion. Steel poles lend themselves most readily to such protection because a "dog guard," made of a piece of larger and thicker pipe, may be slid over the pole from the butt end, and then swaged and shrunk on so that say one-third of its length will be below and two-thirds above the ground line. These dog guards are applied at a red heat, and effectually prevent water entering between the pole and dog guard. They are usually made 2 feet long and ½ inch thick. They thus would at least double the life of a pole of extra-heavy pipe, and frequently treble the life of a pole of standard pipe.

The usual practice in "dog guards" is to make them 2 feet long and of sufficient inside diameter to slide easily over the butt section, as here tabulated.

Butt of pole		Sleeve before swaging			
Nominal size	Outside diameter	Outside diameter	Thickness	Weight per foot	Weight per sleeve
3	3.50	4.50	.337	14.983	29.966
4	4.50	5.563	.375	20.778	41.556
5	5.563	6.625	.432	28.573	57.146
6	6.625	8.00	.500	40.050	80.100
7	7.625	9.00	.500	45.390	90.780
8	8.625	10.00	.500	50.730	101.460
9	9.625	11.00	.500	56.070	112.140
10	10.75	12.00	.500	61.410	122.820
11	11.75	13.00	.500	66.750	133.500
12	12.75	14.00	.500	72.091	144.182
13	14.00	16.00	.500	82.771	165.542

In the case of old poles that need repair, this has been accomplished by the use of a "dog guard" placed over the pole and extending about the ordinary length of joint (18 inches), each way from the injured portion, say 4 feet long, and then the space between sleeve and pole filled with rich Portland cement grout of 1 to 1 or 1 to 2 mixture made up with as little water as will allow it to surely fill all irregularities of the space between sleeve and corroded pole. The following table gives list of appropriate sizes of sleeve.

Butt of pole		Sleeves four (4) feet long			
Nominal size	Outside diameter	Outside diameter	Thickness	Weight per foot	Weight of sleeve
3	3.50	5.00	.355	17.611	70.444
4	4.50	6.625	.432	28.573	114.292
5	5.563	7.625	.500	38.048	152.192
6	6.625	8.625	.500	43.388	173.552
7	7.625	9.625	.500	48.728	194.912
8	8.625	10.75	.500	54.735	218.940
9	9.625	11.75	.500	60.075	240.300
10	10.75	12.75	.500	65.415	261.660
11	11.75	14.00	.500	72.091	288.364
12	12.75	15.00	.500	77.431	309.724
13	14.00	16.00	.500	82.771	331.084

Test Conditions. The test condition (butt fixed for 6 feet and load applied 18 inches below the top) used on these tables is that which the great majority of specifications impose. It has remained the same for many years, so that it may, in a general way, be considered the "Standard" condition for pole tests.

Joints. The joints between the sections of poles are made by inserting the smaller pipe 18 inches into the larger pipe while the latter is at a red heat, swaging down the heated portion and then allowing the joint to cool and shrink. The swaging (viz., reducing the diameter) is done either in a hydraulic press or under a hammer. The former process is expensive when only a few poles are to be made, but is speedy and produces as good work as the hammer on large quantities. The choice

Fig. 47. Shop Joint

of method should be left to the maker, unless customer is willing to stand the increased cost that may be entailed by his specifying the method. The length inserted is almost invariably 18 inches, but other lengths can be worked when called for. Fig. 47 shows how the joint appears when completed. This joint, being assembled in the maker's shop, is usually called a "shop joint" to distinguish it from the following joint.

Field Joint. For shipment of poles over 40 feet long, two railroad cars are generally required, and it is at times economical to make the poles in two parts, with one joint fashioned for customer to assemble at point of erection. This joint is called a "field joint" and is shown in Fig. 48. It will be noted that it is slightly tapered to allow easy insertion when assembling in field, for which it is only necessary to have the two parts accurately in alignment, the lighter one being on rollers, so

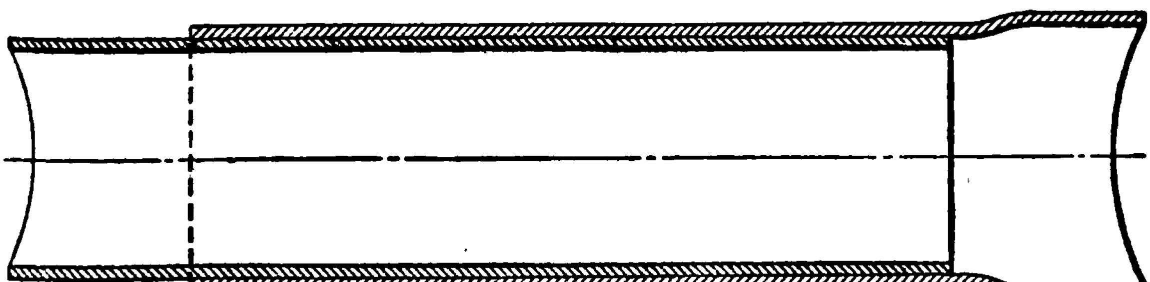


Fig. 48. Field Joint

placed that it may be slid endwise without disturbing the alignment; then heat the outside end for 18 inches to a red heat and insert the smaller pipe and allow to cool. For flag poles of great length such joints are essential, three or four being used on one pole when needed. Another form of field joint has been much used, but it has been discarded because it seriously weakened the pole and was difficult to assemble. It was made by boring the larger pipe and turning the smaller pipe, no taper being used.

Joint Strength. The strength of the swaged joint has frequently been called into question because of careless workmanship or because

attempted with improper tools. When properly made, it meets all practical needs, and all those devices that reduce the section of metal at the joint should be avoided, because they are at best but makeshifts to hide bad workmanship. The regular swaged joint will easily stand the drop test given on page 119. No pole or pipe can be so dropped without shortening its length if dropped on an iron anvil, as has been specified at times. The experiment has been tried on plain pipe (no joints) and it has been found that the length is reduced. The reduction in length is the measure employed to detect telescoping at the joints. While the drop test does not appear to be good from the standpoint of the theoretical engineer, still it is one that any buyer can apply at will anywhere. As a more rational test it has been proposed to subject the poles to an endwise pressure. The objection to this is that customers would have to incur some considerable expense to equip for the test. To determine the resistance of the swaged joints, a number were cut from poles of medium-sized pipes and the endwise thrust measured that would start telescoping. It was found that 30 tons frequently failed to start the joints of ordinary poles, and that some refused to start at 40 tons. These loads are more than twice as great as the loads that such poles would be suited to carry as columns, even if they had no joints.

The question of the effect of the joints on the lateral strength and stiffness of the poles has often been raised. Many experiments have been made which have shown that the joints neither increase nor decrease the lateral strength, stiffness, or set of poles, provided the joints are made with a sufficient insertion. These experiments were made by testing plain pipes, without joints, of various sizes and lengths up to 40 feet. The results were compared with the results of tests of jointed poles. It was found that deflection measures gave about the same average value of the modulus of elasticity with and without joints. The deflections computed, allowing for the double thickness at joints, did not tally as well with experimental results as when the sections were each considered uniform from point of emergence to end. The set on first application of load was as great with plain pipes as with jointed poles. **The crippling never occurred in the joints, but always in the pipe where strain was greatest.**

Theoretical considerations indicate that the proper length of insertion at each joint depends on the size and thickness. When the outside pipe is thin the joint should be a little longer than when it is thick. For thin 13-inch pipe it should be about 20 inches, and for 8-inch pipe about 13 inches will answer. For the sake of uniformity in the tables, ordinary practice has been adhered to, and all joints made with 18-inch insertion. This allows a good margin of excess length except on the 12-inch and 13-inch pipes. For very small pipes the length of joint could be reduced to 7 inches or so, say on 3-inch pipe, when lateral strength is the only consideration; but the practical operations of assembling joints make it advisable to use at least 12 inches on such size.

Service Conditions, Wind Loads, etc. Some specifications involve service conditions for which poles are intended. This Company does not assume liability for poles meeting service conditions. To aid users

to fix on suitable tests for the poles, we give the usual method of wind-load calculation. In this it is usual to assume a maximum wind pressure of 30 pounds per square foot, and equate the resultant wind load to the strength of the pipes at about the elastic limit. Such pressure may be said to correspond to 50 to 90 miles per hour, according to authority accepted. However, it makes little difference what the velocity is, because pressures of 30 pounds to 50 pounds have been repeatedly observed in many places; notably at Greenwich, England. The relation of velocity to pressure is only useful where velocities are recorded and pressure gages not used. But velocity instruments are subject to such great errors that it is not necessary to go into any refinement as to the relation of pressure and velocity. The U. S. Weather Bureau reports the anemometer velocity reading which exceeds the actual average speed of the wind by over 20 per cent. at 60 miles per hour and is thought to vary increasingly at higher speeds but this has not been proven by experiment. The relation, pressure $= f = \frac{V^2}{250} =$ pounds per square foot, relates to actual average wind velocity V in miles per hour. Experiments are stated to show that the pressure on a circular cylinder gives a total load equal to half the diameter multiplied by the length multiplied by the pressure. If the wind moved with an absolutely uniform velocity it would impose a static load, but the wind is always more or less puffy, as may be noted by observing stretched wires, ropes, flags, or trees. They will always be seen swaying or surging. Therefore the load is a "live load," and such is usually considered to impose twice the stress of a "static load." If wires are insulated, the outside diameter of insulation must be used in reckoning wind load. Where snow and ice form, the diameter of the wires may be increased by ¼ inch, or even ½-inch thickness in times of sleet storms. The outside diameter of such incrustation must be used in figuring wind load. It is frequently assumed that the maximum wind pressure and the snow load do not act at the same time. It is practically never necessary to consider the weight of wires, sleet, etc., because any poles that will stand the lateral strain are more than ample to carry, as columns, the vertical loads that will come on them.* Example, — poles spaced 36 per mile, carrying 36 wires No. 10 B. W. G.; 6 cross-arms, 5 inches wide, 6 feet long; wires 25 feet above ground. Wind on wires (no ice or snow) $= (^{0.134}/_{12}) \times \frac{1}{2} \times 2 \times (^{5280}/_{36}) \times 30 \times 36$ equals about 1760 pounds. If ¼-inch sleet is assumed the diameter would be 0.134 plus 0.50, say 0.634, and the load would be about 8370 pounds. Wind on arms would be $6 \times (^{5}/_{12}) \times 6 \times 30$,

* Wind stress may be omitted when computing column strength when the wind stress is less than 25 to 30 per cent. of the stress due to direct column loads in bridges. By inversion; column strength may be omitted when its stress is less than 20 per cent. of the bending stress due to wind. Where it is thought necessary to consider the combined stress due to bending and to loading as a column a generally accepted rule is to add the bending and eccentric loading stress to the direct stress as a column, and keep the sum of the stresses below the permissible stress allowed by one of the approved empirical column formulæ; remembering that a planted pole considered as a column is equivalent to a pivot ended column whose length is twice the length of the pole above ground.

equal to about 450 pounds.* Wind on pole, — for this assume 12 inches diameter and 29 feet long above ground; $(^{12}/_{12}) \times 29 \times 30 \times (1/2)$ equals about 435 pounds. Therefore, equivalent top load is $435 \div 2$, say 218 pounds. Then the wind loads would be

	No ice	With sleet and snow
On wire	1760	8370
On arms	450	450
On pole	218	218
	2428	9038

To use pole table for selecting size of pole required for above loads, note that the tabulated poles are loaded 18 inches below the top and planted 6 feet, therefore 25 feet center of wind load to ground plus 7 feet 6 inches is 32 feet 6 inches. The nearest longer length listed is 33 feet. Pole 7943 will carry the wind load without ice but no pole is listed of sufficient strength to carry the wind load with sleet, etc. By table of Pipe giving I and Q it is seen that the latter wind load would require a butt section larger than 16 inches outside diameter by ½ inch thick. It would, therefore, probably be more economical construction to use guy lines, as is common practice at corner poles. Since a 33 foot pole would hardly afford room to distribute the cross arms it may be necessary to use a longer pole such as 34 feet or 35 feet, say number 8063 or 8103 for the pole with no ice.

Painting. Poles are always painted before leaving the maker's works. Unless customers specify the color, domestic poles are painted black and export poles red. It would appear probable that the best practice would be to dip them in hot molten asphaltic pipe coating, but the demand for such treatment has not yet justified equipment for such dipping.

Pole Tables. The National Tube Company's table of Standard poles is given on the following pages. It is recommended not to depart from the section lengths given in the table. The table is preceded by an explanatory note and the Standard Specification for Poles. These tables are as condensed as possible in order to allow ready comparison and selection.

Tubular Electric Line Pole Tables

These tables of poles, pages 120 to 157, give all essential details for maker and user.

Pole number is given for purpose of reference and identification.

Column headed "Size of butt" gives the nominal size of pipe used in the butt section. The upper sections are each one inch, pipe size, smaller than the section next below, except that 2½-inch is used in 3-inch.

Column headed "Thickness" gives the nominal thickness of each section, from the bottom up, by the use of symbols f and E, which mean standard and extra

* It is not the custom of engineers to consider the wind load a live load on structures firmly held by their foundations nor on pieces rigidly attached thereto. This is different from the above calculation of load on wires which are flexibly attached.

strong, respectively; e.g., *Eff* means extra-strong pipe in bottom section and standard pipe the two upper sections.

Column headed "Maximum load (P)" gives the load that pole will carry, applied 18 inches below the top when pole is planted or "fixed" for a distance of 6 feet. It is figured at 27 000 pounds per square inch fiber stress in the material.

Column headed "Load (L) for deflection D" gives the load that it is suitable to specify when poles must be tested for deflection. This deflection test load is about two-thirds of the maximum load P.

Column headed "Deflection for load L" gives the maximum deflection in inches at point of load when pole is fixed as a cantilever for a distance of 6 feet and load L is applied 18 inches below top. $D =$ deflection limit.

Column headed "Factor R" gives the rate of deflection in inches per 100 pounds load.

Column headed "Factor m" gives a factor for computing the approximate deflection D' at any point situated "n" inches above the point of application of the load, by means of formula $D' = D(m+n)/m$, all other conditions remaining as before.

By reason of the slight, unavoidable variations in manufacture, the data shown in the following tubular electric line pole tables are not absolutely correct, but the element of error is very small.

Any pole given in these tables will conform to the following specifications:

Specifications. All poles shall be composed of wrought-steel pipes. Joints shall be made by inserting the smaller pipe cold into the larger pipe a distance of 18 inches, and while the latter is hot, swaging it upon the smaller and allowing them to cool and shrink. No shims, wires, liners, pins, rivets, punch marks, or any device that weakens material at joint will be allowed.

Any pole when fixed for a distance of six feet from the butt end and tested as a cantilever with the load given in column P, applied 18 inches below the top, shall not show a set or permanent deflection in excess of 10 per cent of the temporary deflection under this load, but this set limit may not be placed at less than ½ inch in any case. Any pole tested as before, but with the load in pounds given in column L, shall not show a temporary deflection in inches, at the point of load, exceeding the figure given in column D.

Any pole when dropped three times, butt foremost, from a height of six feet upon a solid wood block on a rigid base shall not telescope at the joints.

Weight of completed pole shall not vary more than 5 per cent above or 5 per cent below the weight given in column headed "Weight."

The following list gives pipes used for poles given on pages 120 to 157.

	Nominal size	Thickness	Weight per foot	Moment of inertia		Nominal size	Thickness	Weight per foot	Moment of inertia
Standard	2½	.203	5.793	1.5296	Extra strong	2½	.276	7.661	1.9242
	3	.216	7.575	3.0172		3	.300	10.252	3.8943
	4	.237	10.790	7.2326		4	.337	14.983	9.6105
	5	.258	14.617	15.162		5	.375	20.778	20.671
	6	.280	18.974	28.142		6	.432	28.573	40.491
	7	.301	23.544	46.515		7	.500	38.048	71.370
	8	.322	28.554	72.489		8	.500	43.388	105.72
	9	.342	33.907	107.58		9	.500	48.728	149.63
	10	.365	40.483	160.73		10	.500	54.735	211.95
	11	.375	45.557	216.98		11	.500	60.075	280.12
	12	.375	49.562	279.33		12	.500	65.415	361.54
	13	.375	54.568	372.76		13	.500	72.091	483.76

Length of Pole, 22 Feet

Sections: 18 feet 6 inches and 5 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7000	3	169	*ff*	267	180	4.19	2.33	114
7001	4	238	"	499	350	3.41	.975	113
7002	5	324	"	846	550	2.55	.465	114
7003	6	425	"	1 318	900	2.25	.250	114
7004	7	530	"	1 893	1300	1.96	.151	115
7005	8	647	"	2 609	1700	1.65	.0970	115
7006	9	770	"	3 469	2300	1.50	.0654	115
7007	10	919	"	4 641	3100	1.36	.0438	116
7008	11	1046	"	5 732	3800	1.23	.0324	116
7009	12	1146	"	6 801	4500	1.13	.0252	116
7010	13	1258	"	8 265	5500	1.03	.0188	115
7011	3	220	*Ef*	347	220	3.96	1.80	113
7012	4	315	"	663	450	3.30	.735	112
7013	5	433	"	1 141	750	2.58	.345	113
7014	6	602	"	1 897	1300	2.26	.174	113
7015	7	798	"	2 905	1900	1.88	.0988	113
7016	8	920	"	3 805	2500	1.67	.0666	114
7017	9	1044	"	4 826	3200	1.50	.0471	114
7018	10	1182	"	6 120	4000	1.33	.0333	114
7019	11	1314	"	7 401	5000	1.26	.0251	114
7020	12	1438	"	8 802	5800	1.12	.0194	114
7021	13	1582	"	10 727	7200	1.05	.0146	115
7022	3	229	*EE*	347	220	3.96	1.80	114
7023	4	329	"	663	450	3.30	.734	113
7024	5	454	"	1 141	750	2.58	.344	114
7025	6	632	"	1 897	1300	2.26	.174	114
7026	7	846	"	2 905	1900	1.87	.0986	115
7027	8	993	"	3 805	2500	1.66	.0665	115
7028	9	1118	"	4 826	3200	1.50	.0470	116
7029	10	1256	"	6 120	4000	1.33	.0332	115
7030	11	1385	"	7 401	5000	1.26	.0251	115
7031	12	1510	"	8 802	5800	1.12	.0194	115
7032	13	1661	"	10 727	7200	1.05	.0146	116

Length of Pole, 23 Feet

Sections: 19 feet 6 inches and 5 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7033	3	177	*ff*	250	170	4.85	2.85	122
7034	4	249	"	466	300	3.57	1.19	122
7035	5	339	"	791	550	3.12	.567	122
7036	6	444	"	1 233	800	2.44	.305	122
7037	7	553	"	1 771	1200	2.22	.185	123
7038	8	675	"	2 440	1600	1.90	.119	123
7039	9	804	"	3 245	2200	1.76	.0798	123
7040	10	959	"	4 342	2900	1.55	.0535	123
7041	11	1092	"	5 362	3600	1.42	.0395	123
7042	12	1195	"	6 362	4200	1.29	.0307	123
7043	13	1313	"	7 732	5200	1.20	.0230	123
7044	3	230	*Ef*	324	220	4.84	2.20	121
7045	4	330	"	620	400	3.59	.897	120
7046	5	454	"	1 068	700	2.95	.421	121
7047	6	631	"	1 774	1200	2.56	.213	121
7048	7	836	"	2 718	1800	2.18	.121	121
7049	8	964	"	3 559	2400	1.95	.0813	122
7050	9	1093	"	4 515	3000	1.73	.0575	122
7051	10	1236	"	5 725	3800	1.54	.0406	122
7052	11	1375	"	6 923	4500	1.38	.0306	122
7053	12	1503	"	8 234	5500	1.31	.0238	123
7054	13	1654	"	10 034	6800	1.21	.0178	124
7055	3	239	*EE*	324	220	4.84	2.20	122
7056	4	344	"	620	400	3.58	.896	122
7057	5	475	"	1 067	700	2.95	.421	122
7058	6	660	"	1 774	1200	2.54	.212	122
7059	7	884	"	2 718	1800	2.16	.120	123
7060	8	1036	"	3 559	2400	1.95	.0812	123
7061	9	1167	"	4 514	3000	1.73	.0575	124
7062	10	1310	"	5 725	3800	1.54	.0405	123
7063	11	1446	"	6 923	4500	1.38	.0306	123
7064	12	1576	"	8 234	5500	1.31	.0238	124
7065	13	1733	"	10 034	6800	1.21	.0178	124

Length of Pole, 24 Feet

Sections: 18 feet 6 inches and 7 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7066	3	181	ff	235	160	5.57	3.48	127
7067	4	253	"	438	300	4.38	1.46	124
7068	5	346	"	743	500	3.47	.694	126
7069	6	454	"	1158	750	2.79	.372	127
7070	7	568	"	1664	1100	2.48	.225	128
7071	8	694	"	2292	1500	2.16	.144	129
7072	9	827	"	3049	2000	1.94	.0968	129
7073	10	987	"	4079	2700	1.75	.0648	129
7074	11	1127	"	5037	3400	1.63	.0480	131
7075	12	1237	"	5977	4000	1.49	.0372	130
7076	13	1357	"	7263	4800	1.34	.0280	131
7077	3	231	Ef	305	200	5.40	2.70	124
7078	4	331	"	582	400	4.44	1.11	121
7079	5	455	"	1002	650	3.37	.519	122
7080	6	631	"	1667	1100	2.88	.262	123
7081	7	836	"	2553	1700	2.52	.148	124
7082	8	967	"	3343	2200	2.19	.0996	125
7083	9	1101	"	4241	2800	1.97	.0702	126
7084	10	1249	"	5378	3600	1.78	.0495	127
7085	11	1395	"	6503	4200	1.57	.0374	128
7086	12	1529	"	7735	5200	1.50	.0289	128
7087	13	1681	"	9426	6200	1.34	.0216	128
7088	3	244	EE	305	200	5.36	2.68	126
7089	4	350	"	582	400	4.40	1.10	124
7090	5	484	"	1002	650	3.34	.514	126
7091	6	673	"	1667	1100	2.85	.259	127
7092	7	903	"	2553	1700	2.50	.147	128
7093	8	1069	"	3343	2200	2.17	.0986	129
7094	9	1205	"	4241	2800	1.95	.0696	130
7095	10	1353	"	5378	3600	1.77	.0491	130
7096	11	1495	"	6503	4200	1.56	.0371	130
7097	12	1631	"	7735	5200	1.50	.0288	131
7098	13	1792	"	9426	6200	1.33	.0214	129

Length of Pole, 24 Feet

Sections: 19 feet, 4 feet, and 4 feet

Number	Size of butt	Weight	Thickness	Maximum load P'	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7099	4	259	*fff*	438	300	4.35	1.45	125
7100	5	351	"	743	500	3.45	.690	126
7101	6	463	"	1159	750	2.78	.371	127
7102	7	581	"	1664	1100	2.46	.224	129
7103	8	713	"	2292	1500	2.16	.144	129
7104	9	853	"	3049	2000	1.93	.0966	129
7105	10	1020	"	4079	2700	1.75	.0647	129
7106	11	1164	"	5037	3400	1.63	.0478	130
7107	12	1287	"	5977	4000	1.49	.0372	130
7108	13	1418	"	7264	4800	1.34	.0279	131
7109	4	339	*Eff*	582	400	4.40	1.10	122
7110	5	463	"	1002	650	3.35	.515	123
7111	6	645	"	1667	1100	2.86	.260	124
7112	7	856	"	2553	1700	2.50	.147	124
7113	8	995	"	3343	2200	2.18	.0992	126
7114	9	1134	"	4241	2800	1.96	.0699	127
7115	10	1289	"	5378	3600	1.77	.0492	127
7116	11	1440	"	6503	4200	1.56	.0372	128
7117	12	1587	"	7735	5200	1.50	.0288	129
7118	13	1751	"	9426	6200	1.34	.0216	130
7119	4	349	*EEf*	582	400	4.36	1.09	124
7120	5	480	"	1002	650	3.33	.512	125
7121	6	669	"	1667	1100	2.84	.258	126
7122	7	895	"	2553	1700	2.48	.146	127
7123	8	1053	"	3343	2200	2.16	.0984	129
7124	9	1193	"	4241	2800	1.95	.0695	130
7125	10	1349	"	5378	3600	1.76	.0490	130
7126	11	1496	"	6503	4200	1.56	.0371	131
7127	12	1645	"	7735	5200	1.49	.0287	131
7128	13	1814	"	9426	6200	1.33	.0215	131
7129	4	357	*EEE*	582	400	4.36	1.09	125
7130	5	491	"	1002	650	3.33	.512	126
7131	6	685	"	1667	1100	2.84	.258	127
7132	7	918	"	2553	1700	2.48	.146	128
7133	8	1091	"	3343	2200	2.16	.0984	129
7134	9	1251	"	4241	2800	1.95	.0695	130
7135	10	1408	"	5378	3600	1.76	.0490	130
7136	11	1556	"	6503	4200	1.56	.0371	131
7137	12	1702	"	7735	5200	1.49	.0287	132
7138	13	1872	"	9426	6200	1.33	.0215	131

Length of Pole, 25 Feet

Sections: 19 feet 6 inches and 7 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7139	3	188	*ff*	221	150	6.21	4.14	135
7140	4	264	"	413	280	4.87	1.74	133
7141	5	360	"	701	450	3.71	.825	134
7142	6	473	"	1092	750	3.32	.443	135
7143	7	591	"	1569	1000	2.68	.268	136
7144	8	722	"	2161	1400	2.39	.171	137
7145	9	861	"	2875	1900	2.19	.115	137
7146	10	1027	"	3845	2600	2.01	.0773	137
7147	11	1173	"	4749	3200	1.83	.0572	138
7148	12	1286	"	5635	3900	1.73	.0444	138
7149	13	1412	"	6848	4800	1.60	.0333	138
7150	3	241	*Ef*	287	190	6.10	3.21	132
7151	4	346	"	549	350	4.62	1.32	129
7152	5	475	"	945	650	4.01	.617	131
7153	6	660	"	1572	1000	3.11	.311	131
7154	7	874	"	2407	1600	2.82	.176	132
7155	8	1011	"	3152	2100	2.50	.119	133
7156	9	1150	"	3998	2700	2.25	.0835	134
7157	10	1304	"	5071	3400	2.00	.0589	134
7158	11	1456	"	6132	4000	1.78	.0445	136
7159	12	1595	"	7293	4800	1.65	.0344	136
7160	13	1753	"	8888	6000	1.55	.0258	137
7161	3	255	*EE*	287	190	6.06	3.19	135
7162	4	365	"	549	350	4.59	1.31	132
7163	5	505	"	945	650	3.98	.612	134
7164	6	701	"	1572	1000	3.09	.309	135
7165	7	941	"	2407	1600	2.80	.175	136
7166	8	1112	"	3152	2100	2.48	.118	137
7167	9	1254	"	3998	2700	2.24	.0830	138
7168	10	1408	"	5071	3400	1.99	.0585	137
7169	11	1555	"	6132	4000	1.77	.0442	138
7170	12	1696	"	7293	4800	1.65	.0343	139
7171	13	1864	"	8888	6000	1.54	.0256	138

Length of Pole, 25 Feet

Sections: 19 feet, 5 feet, and 4 feet

Number	Size of butt	Weight	Thick-ness	Maxi-mum load P	Load for deflec-tion D L	Deflec-tion for load L D	Factor R	Factor m
7172	4	266	*fff*	413	280	4.90	1.75	130
7173	5	362	"	701	450	3.74	.830	132
7174	6	477	"	1092	750	3.34	.445	134
7175	7	600	"	1569	1000	2.69	.269	135
7176	8	737	"	2161	1400	2.41	.172	136
7177	9	881	"	2875	1900	2.20	.116	136
7178	10	1053	"	3845	2600	2.02	.0775	137
7179	11	1205	"	4749	3200	1.83	.0573	138
7180	12	1332	"	5635	3900	1.73	.0444	138
7181	13	1468	"	6848	4800	1.60	.0333	138
7182	4	346	*Eff*	549	350	4.66	1.33	126
7183	5	474	"	945	650	4.05	.623	127
7184	6	660	"	1572	1000	3.14	.314	129
7185	7	875	"	2407	1600	2.85	.178	130
7186	8	1018	"	3152	2100	2.50	.119	131
7187	9	1162	"	3998	2700	2.27	.0840	133
7188	10	1323	"	5071	3400	2.01	.0592	134
7189	11	1480	"	6132	4000	1.79	.0447	135
7190	12	1633	"	7293	4800	1.66	.0345	135
7191	13	1800	"	8888	6000	1.55	.0259	136
7192	4	360	*EEf*	549	350	4.62	1.32	130
7193	5	495	"	945	650	4.00	.616	131
7194	6	689	"	1572	1000	3.10	.310	132
7195	7	923	"	2407	1600	2.80	.175	134
7196	8	1091	"	3152	2100	2.48	.118	136
7197	9	1236	"	3998	2700	2.25	.0832	137
7198	10	1397	"	5071	3400	2.00	.0587	137
7199	11	1551	"	6132	4000	1.77	.0443	137
7200	12	1705	"	7293	4800	1.65	.0343	137
7201	13	1879	"	8888	6000	1.54	.0257	138
7202	4	367	*EEE*	549	350	4.62	1.32	130
7203	5	506	"	945	650	4.00	.616	132
7204	6	706	"	1572	1000	3.10	.310	133
7205	7	947	"	2407	1600	2.80	.175	134
7206	8	1129	"	3152	2100	2.48	.118	136
7207	9	1294	"	3998	2700	2.25	.0832	137
7208	10	1456	"	5071	3400	2.00	.0587	137
7209	11	1610	"	6132	4000	1.77	.0443	137
7210	12	1762	"	7293	4800	1.65	.0343	138
7211	13	1937	"	8888	6000	1.54	.0257	138

Length of Pole, 26 Feet

Sections: 20 feet 6 inches and 7 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7212	3	196	*ff*	209	140	6.83	4.88	143
7213	4	275	"	391	250	5.13	2.05	141
7214	5	375	"	663	450	4.38	.973	142
7215	6	492	"	1033	700	3.66	.523	144
7216	7	615	"	1484	1000	3.16	.316	145
7217	8	751	"	2044	1400	2.83	.202	145
7218	9	895	"	2719	1800	2.45	.136	145
7219	10	1068	"	3638	2400	2.19	.0912	145
7220	11	1218	"	4493	3000	2.03	.0675	147
7221	12	1336	"	5330	3600	1.88	.0523	146
7222	13	1467	"	6478	4200	1.65	.0393	147
7223	3	252	*Ef*	272	180	6.82	3.79	140
7224	4	361	"	519	350	5.43	1.55	137
7225	5	496	"	894	600	4.36	.726	139
7226	6	689	"	1487	1000	3.66	.366	140
7227	7	912	"	2277	1500	3.12	.208	140
7228	8	1054	"	2982	2000	2.80	.140	141
7229	9	1199	"	3782	2500	2.46	.0985	142
7230	10	1359	"	4797	3200	2.22	.0695	143
7231	11	1516	"	5800	3900	2.05	.0525	145
7232	12	1660	"	6899	4500	1.83	.0406	144
7233	13	1825	"	8407	5500	1.67	.0304	145
7234	3	265	*EE*	272	180	6.79	3.77	143
7235	4	380	"	519	350	5.39	1.54	141
7236	5	525	"	894	600	4.33	.721	142
7237	6	730	"	1487	1000	3.64	.364	143
7238	7	979	"	2277	1500	3.09	.206	144
7239	8	1156	"	2982	2000	2.78	.139	146
7240	9	1302	"	3782	2500	2.45	.0979	146
7241	10	1462	"	4797	3200	2.21	.0691	146
7242	11	1615	"	5800	3900	2.04	.0522	146
7243	12	1761	"	6899	4500	1.82	.0405	146
7244	13	1936	"	8407	5500	1.66	.0302	146

Length of Pole, 26 Feet

Sections: 18 feet 6 inches, 6 feet 6 inches, and 4 feet

Number	Size of butt	Weight	Thick-ness	Maxi-mum load P	Load for deflec-tion D L	Deflec-tion for load L D	Factor R	Factor m
7245	4	272	fff	391	250	5.28	2.11	134
7246	5	371	"	663	450	4.49	.998	137
7247	6	490	"	1033	700	3.74	.534	139
7248	7	617	"	1484	1000	3.21	.321	141
7249	8	758	"	2044	1400	2.87	.205	142
7250	9	907	"	2719	1800	2.48	.138	143
7251	10	1084	"	3638	2400	2.22	.0924	143
7252	11	1243	"	4493	3000	2.04	.0681	145
7253	12	1376	"	5330	3600	1.90	.0527	145
7254	13	1515	"	6478	4200	1.66	.0396	146
7255	4	350	Eff	519	350	5.71	1.63	129
7256	5	480	"	894	600	4.55	.758	131
7257	6	667	"	1487	1000	3.81	.381	132
7258	7	885	"	2277	1500	3.23	.215	133
7259	8	1032	"	2982	2000	2.88	.144	136
7260	9	1181	"	3782	2500	2.53	.101	137
7261	10	1347	"	4797	3200	2.28	.0711	139
7262	11	1511	"	5800	3900	2.09	.0535	141
7263	12	1668	"	6899	4500	1.86	.0413	141
7264	13	1839	"	8407	5500	1.70	.0309	141
7265	4	368	EEf	519	350	5.57	1.59	134
7266	5	507	"	894	600	4.45	.741	136
7267	6	706	"	1487	1000	3.73	.373	137
7268	7	947	"	2277	1500	3.15	.210	140
7269	8	1126	"	2982	2000	2.80	.140	142
7270	9	1277	"	3782	2500	2.47	.0988	143
7271	10	1443	"	4797	3200	2.23	.0698	143
7272	11	1603	"	5800	3900	2.06	.0527	145
7273	12	1763	"	6899	4500	1.84	.0408	145
7274	13	1941	"	8407	5500	1.67	.0304	143
7275	4	375	EEE	519	350	5.57	1.59	134
7276	5	518	"	894	600	4.45	.741	136
7277	6	722	"	1487	1000	3.72	.372	138
7278	7	971	"	2277	1500	3.15	.210	140
7279	8	1164	"	2982	2000	2.80	.140	143
7280	9	1335	"	3782	2500	2.47	.0988	143
7281	10	1502	"	4797	3200	2.23	.0698	144
7282	11	1662	"	5800	3900	2.06	.0527	145
7283	12	1819	"	6899	4500	1.84	.0408	146
7284	13	1999	"	8407	5500	1.67	.0304	143

Length of Pole, 27 Feet

Sections: 18 feet 6 inches and 10 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7285	3	198	*ff*	199	130	7.70	5.92	145
7286	4	276	"	371	250	6.30	2.52	141
7287	5	378	"	629	400	4.72	1.18	144
7288	6	498	"	980	650	4.10	.631	146
7289	7	625	"	1408	950	3.59	.378	148
7290	8	764	"	1940	1300	3.15	.242	149
7291	9	913	"	2580	1700	2.75	.162	150
7292	10	1088	"	3451	2300	2.51	.109	150
7293	11	1249	"	4262	2800	2.24	.0800	152
7294	12	1374	"	5057	3400	2.10	.0619	152
7295	13	1506	"	6146	4000	1.86	.0465	152
7296	3	249	*Ef*	258	170	7 96	4.68	139
7297	4	353	"	493	350	6.86	1.96	134
7298	5	487	"	848	550	4.98	.906	137
7299	6	675	"	1410	950	4.32	.455	138
7300	7	893	"	2160	1400	3.58	.256	140
7301	8	1038	"	2829	1900	3.25	.171	142
7302	9	1187	"	3588	2400	2.88	.120	144
7303	10	1351	"	4551	3000	2.53	.0842	145
7304	11	1517	"	5503	3700	2.33	.0631	148
7305	12	1666	"	6545	4500	2.19	.0486	147
7306	13	1830	"	7976	5200	1.90	.0365	147
7307	3	267	*EE*	258	170	7.77	4.57	144
7308	4	381	"	493	350	6.65	1.90	140
7309	5	529	"	848	550	4.83	.879	143
7310	6	734	"	1410	950	4.19	.441	145
7311	7	989	"	2160	1400	3.47	.248	147
7312	8	1183	"	2829	1900	3.14	.165	150
7313	9	1335	"	3588	2400	2.78	.116	151
7314	10	1499	"	4551	3000	2.47	.0822	151
7315	11	1659	"	5503	3700	2.29	.0619	152
7316	12	1811	"	6545	4500	2.16	.0479	152
7317	13	1988	"	7976	5200	1.86	.0358	151

Length of Pole, 27 Feet

Sections: 18 feet 6 inches, 6 feet 6 inches, and 5 feet

Number	Size of butt	Weight	Thickness	Maximum load *P*	Load for deflection *D* *L*	Deflection for load *L* *D*	Factor *R*	Factor *m*
7318	4	278	*fff*	371	250	6.30	2.52	138
7319	5	378	"	629	400	4.76	1.19	140
7320	6	500	"	980	650	4.11	.632	144
7321	7	631	"	1408	950	3.60	.379	147
7322	8	777	"	1940	1300	3.15	.242	148
7323	9	931	"	2580	1700	2.77	.163	149
7324	10	1113	"	3451	2300	2.51	.109	149
7325	11	1276	"	4262	2800	2.24	.0801	151
7326	12	1417	"	5057	3400	2.11	.0620	151
7327	13	1561	"	6146	4000	1.86	.0465	152
7328	4	356	*Eff*	493	350	6.86	1.96	131
7329	5	487	"	848	550	5.01	.910	133
7330	6	678	"	1410	950	4.33	.456	135
7331	7	900	"	2160	1400	3.60	.257	137
7332	8	1051	"	2829	1900	3.25	.171	140
7333	9	1204	"	3588	2400	2.88	.120	143
7334	10	1375	"	4551	3000	2.53	.0844	144
7335	11	1545	"	5503	3700	2.34	.0632	147
7336	12	1709	"	6545	4500	2.19	.0487	147
7337	13	1884	"	7976	5200	1.90	.0365	147
7338	4	374	*EEf*	493	350	6.65	1.90	136
7339	5	515	"	848	550	4.86	.883	138
7340	6	716	"	1410	950	4.21	.443	141
7341	7	962	"	2160	1400	3.49	.249	144
7342	8	1145	"	2829	1900	3.15	.166	147
7343	9	1301	"	3588	2400	2.81	.117	149
7344	10	1472	"	4551	3000	2.47	.0823	149
7345	11	1637	"	5503	3700	2.29	.0620	150
7346	12	1803	"	6545	4500	2.16	.0479	150
7347	13	1987	"	7976	5200	1.87	.0359	151
7348	4	383	*EEE*	493	350	6.65	1.90	138
7349	5	528	"	848	550	4.85	.882	140
7350	6	737	"	1410	950	4.20	.442	142
7351	7	991	"	2160	1400	3.47	.248	145
7352	8	1193	"	2829	1900	3.14	.165	149
7353	9	1373	"	3588	2400	2.81	.117	150
7354	10	1546	"	4551	3000	2.47	.0822	150
7355	11	1711	"	5503	3700	2.29	.0619	151
7356	12	1874	"	6545	4500	2.16	.0479	151
7357	13	2060	"	7976	5200	1.87	.0359	151

Length of Pole, 28 Feet

Sections: 19 feet and 10 feet 6 inches

Number	Size of butt	Weight	Thickness	Maximum load *P*	Load for deflection *D* *L*	Deflection for load *L* *D*	Factor *R*	Factor *m*
7358	3	205	*ff*	189	130	8.96	6.89	152
7359	4	285	"	352	220	6.45	2.93	148
7360	5	391	"	598	400	5.52	1.38	151
7361	6	514	"	932	600	4.41	.735	153
7362	7	646	"	1339	900	3.96	.449	156
7363	8	790	"	1845	1200	3.37	.281	157
7364	9	944	"	2454	1600	3.02	.189	158
7365	10	1126	"	3283	2200	2.79	.127	158
7366	11	1292	"	4054	2700	2.51	.0931	160
7367	12	1421	"	4810	3200	2.30	.0720	160
7368	13	1558	"	5846	3900	2.11	.0541	159
7369	3	257	*Ef*	245	160	8.74	5.46	146
7370	4	365	"	468	300	6.87	2.29	141
7371	5	503	"	807	550	5.83	1.06	144
7372	6	697	"	1342	900	4.77	.530	145
7373	7	922	"	2055	1400	4.19	.299	146
7374	8	1071	"	2691	1800	3.58	.199	149
7375	9	1226	"	3413	2300	3.22	.140	151
7376	10	1395	"	4329	2900	2.84	.0980	152
7377	11	1567	"	5234	3500	2.57	.0735	155
7378	12	1721	"	6226	4200	2.38	.0567	155
7379	13	1891	"	7587	5000	2.13	.0426	155
7380	3	276	*EE*	245	160	8.53	5.33	151
7381	4	393	"	468	300	6.63	2.21	147
7382	5	547	"	807	550	5.61	1.02	150
7383	6	759	"	1342	900	4.63	.514	152
7384	7	1022	"	2055	1400	4.06	.289	154
7385	8	1224	"	2691	1800	3.46	.192	158
7386	9	1381	"	3413	2300	3.11	.135	159
7387	10	1551	"	4329	2900	2.77	.0956	159
7388	11	1716	"	5234	3500	2.52	.0720	160
7389	12	1874	"	6226	4200	2.34	.0557	160
7390	13	2057	"	7587	5000	2.09	.0417	160

Length of Pole, 28 Feet

Sections: 19 feet, 7 feet, and 5 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7391	4	287	*fff*	352	220	6.47	2.94	145
7392	5	391	"	598	400	5.52	1.38	148
7393	6	517	"	932	600	4.42	.736	151
7394	7	653	"	1339	900	3.97	.441	154
7395	8	803	"	1845	1200	3.38	.282	156
7396	9	962	"	2454	1600	3.02	.189	157
7397	10	1150	"	3283	2200	2.79	.127	157
7398	11	1319	"	4054	2700	2.52	.0932	159
7399	12	1464	"	4810	3200	2.30	.0720	159
7400	13	1613	"	5846	3900	2.11	.0541	159
7401	4	367	*Eff*	468	300	6.87	2.29	138
7402	5	503	"	807	550	5.83	1.06	140
7403	6	700	"	1342	900	4.79	.532	142
7404	7	928	"	2055	1400	4.20	.300	144
7405	8	1084	"	2691	1800	3.60	.200	147
7406	9	1243	"	3413	2300	3.22	.140	150
7407	10	1420	"	4329	2900	2.84	.0981	151
7408	11	1595	"	5234	3500	2.58	.0736	154
7409	12	1764	"	6226	4200	2.38	.0567	154
7410	13	1945	"	7587	5000	2.13	.0426	155
7411	4	386	*EEf*	468	300	6.66	2.22	143
7412	5	532	"	807	550	5.67	1.03	145
7413	6	741	"	1342	900	4.64	.515	148
7414	7	995	"	2055	1400	4.05	.289	151
7415	8	1186	"	2691	1800	3.47	.193	155
7416	9	1347	"	3413	2300	3.13	.136	156
7417	10	1523	"	4329	2900	2.78	.0957	156
7418	11	1694	"	5234	3500	2.52	.0720	158
7419	12	1866	"	6226	4200	2.34	.0557	159
7420	13	2056	"	7587	5000	2.09	.0418	159
7421	4	395	*EEE*	468	300	6.66	2.22	144
7422	5	546	"	807	550	5.67	1.03	147
7423	6	762	"	1342	900	4.64	.515	149
7424	7	1025	"	2055	1400	4.05	.289	152
7425	8	1234	"	2691	1800	3.46	.192	156
7426	9	1419	"	3413	2300	3.13	.136	158
7427	10	1597	"	4329	2900	2.77	.0956	157
7428	11	1768	"	5234	3500	2.52	.0720	159
7429	12	1937	"	6226	4200	2.34	.0557	160
7430	13	2128	"	7587	5000	2.09	.0418	160

Length of Pole, 28 Feet

Sections: 21 feet, 5 feet, and 5 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7431	4	294	*fff*	352	220	6.20	2.82	150
7432	5	399	"	598	400	5.36	1.34	152
7433	6	526	"	932	600	4.31	.718	155
7434	7	662	"	1339	900	3.90	.433	156
7435	8	813	"	1845	1200	3.34	.278	158
7436	9	972	"	2454	1600	2.98	.186	159
7437	10	1163	"	3283	2200	2.75	.125	159
7438	11	1330	"	4054	2700	2.49	.0921	160
7439	12	1472	"	4810	3200	2.29	.0715	161
7440	13	1623	"	5846	3900	2.09	.0537	161
7441	4	382	*Eff*	468	300	6.48	2.16	144
7442	5	522	"	807	550	5.56	1.01	146
7443	6	728	"	1342	900	4.56	.507	148
7444	7	966	"	2055	1400	4.02	.287	150
7445	8	1124	"	2691	1800	3.47	.193	152
7446	9	1283	"	3413	2300	3.13	.136	154
7447	10	1461	"	4329	2900	2.77	.0956	155
7448	11	1634	"	5234	3500	2.52	.0719	157
7449	12	1804	"	6226	4200	2.34	.0556	158
7450	13	1990	"	7587	5000	2.08	.0416	157
7451	4	396	*EEf*	468	300	6.39	2.13	148
7452	5	543	"	807	550	5.48	.996	150
7453	6	757	"	1342	900	4.51	.501	152
7454	7	1014	"	2055	1400	3.96	.283	154
7455	8	1196	"	2691	1800	3.42	.190	157
7456	9	1357	"	3413	2300	3.08	.134	158
7457	10	1535	"	4329	2900	2.74	.0946	159
7458	11	1705	"	5234	3500	2.50	.0714	159
7459	12	1876	"	6226	4200	2.32	.0553	160
7460	13	2069	"	7587	5000	2.07	.0413	159
7461	4	405	*EEE*	468	300	6.39	2.13	150
7462	5	557	"	807	550	5.47	.995	151
7463	6	778	"	1342	900	4.50	.500	153
7464	7	1044	"	2055	1400	3.96	.283	156
7465	8	1244	"	2691	1800	3.42	.190	158
7466	9	1430	"	3413	2300	3.08	.134	160
7467	10	1609	"	4329	2900	2.74	.0945	160
7468	11	1779	"	5234	3500	2.50	.0713	160
7469	12	1947	"	6226	4200	2.32	.0552	161
7470	13	2142	"	7587	5000	2.07	.0413	160

Length of Pole, 29 Feet

Sections: 20 feet and 10 feet 6 inches

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7471	3	212	*ff*	180	120	9.48	7.90	160
7472	4	296	"	336	220	7.37	3.35	156
7473	5	405	"	570	400	6.32	1.58	159
7474	6	533	"	889	600	5.06	.843	161
7475	7	670	"	1277	850	4.30	.506	164
7476	8	819	"	1759	1200	3.88	.323	165
7477	9	978	"	2340	1600	3.47	.217	166
7478	10	1167	"	3130	2100	3.05	.145	166
7479	11	1337	"	3866	2600	2.78	.107	168
7480	12	1471	"	4587	3100	2.57	.0830	168
7481	13	1613	"	5574	3700	2.31	.0623	167
7482	3	267	*Ef*	234	160	9.98	6.24	154
7483	4	380	"	447	300	7.80	2.60	149
7484	5	523	"	769	500	6.05	1.21	152
7485	6	725	"	1279	850	5.15	.606	153
7486	7	960	"	1959	1300	4.45	.342	154
7487	8	1115	"	2566	1700	3.88	.228	157
7488	9	1274	"	3254	2200	3.52	.160	159
7489	10	1450	"	4127	2800	3.14	.112	160
7490	11	1627	"	4991	3300	2.79	.0844	163
7491	12	1787	"	5936	4000	2.60	.0651	164
7492	13	1963	"	7234	4800	2.34	.0488	163
7493	3	286	*EE*	234	160	9.78	6.11	160
7494	4	408	"	447	300	7.59	2.53	155
7495	5	568	"	769	500	5.85	1.17	159
7496	6	787	"	1279	850	5.01	.589	160
7497	7	1060	"	1959	1300	4.30	.331	163
7498	8	1267	"	2566	1700	3.76	.221	166
7499	9	1430	"	3254	2200	3.43	.156	167
7500	10	1605	"	4127	2800	3.08	.110	167
7501	11	1776	"	4991	3300	2.74	.0829	168
7502	12	1939	"	5936	4000	2.57	.0642	169
7503	13	2129	"	7234	4800	2.30	0480	167

Length of Pole, 29 Feet

Sections: 18 feet 6 inches, 7 feet, and 6 feet 6 inches

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7504	4	291	*fff*	336	220	7.74	3.52	147
7505	5	395	"	570	400	6.60	1.65	148
7506	6	524	"	889	600	5.23	.872	153
7507	7	663	"	1277	850	4.41	.519	158
7508	8	817	"	1759	1200	3.96	.330	160
7509	9	980	"	2340	1600	3.54	.221	161
7510	10	1173	"	3130	2100	3.11	.148	162
7511	11	1348	"	3866	2600	2.83	.109	164
7512	12	1500	"	4587	3100	2.60	.0838	165
7513	13	1654	"	5574	3700	2.33	.0630	165
7514	4	368	*Eff*	447	300	8.40	2.80	138
7515	5	504	"	769	500	6.45	1.29	139
7516	6	702	"	1279	850	5.46	.642	143
7517	7	931	"	1959	1300	4.68	.360	146
7518	8	1091	"	2566	1700	4.05	.238	150
7519	9	1254	"	3254	2200	3.65	.166	153
7520	10	1435	"	4127	2800	3.25	.116	155
7521	11	1616	"	4991	3300	2.86	.0866	158
7522	12	1792	"	5936	4000	2.66	.0665	159
7523	13	1978	"	7234	4800	2.40	.0501	160
7524	4	387	*EEf*	447	300	8.04	2.68	142
7525	5	534	"	769	500	6.15	1.23	144
7526	6	743	"	1279	850	5.23	.615	148
7527	7	998	"	1959	1300	4.46	.343	152
7528	8	1192	"	2566	1700	3.84	.226	157
7529	9	1358	"	3254	2200	3.50	.159	159
7530	10	1539	"	4127	2800	3.14	.112	160
7531	11	1715	"	4991	3300	2.78	.0842	162
7532	12	1894	"	5936	4000	2.60	.0649	164
7533	13	2088	"	7234	4800	2.34	.0487	164
7534	4	399	*EEE*	447	300	7.98	2.66	145
7535	5	551	"	769	500	6.15	1.23	147
7536	6	770	"	1279	850	5.20	.612	151
7537	7	1037	"	1959	1300	4.43	.341	155
7538	8	1255	"	2566	1700	3.83	.225	161
7539	9	1452	"	3254	2200	3.48	.158	163
7540	10	1635	"	4127	2800	3.14	.112	163
7541	11	1811	"	4991	3300	2.77	.0839	165
7542	12	1986	"	5936	4000	2.59	.0648	166
7543	13	2182	"	7234	4800	2.33	.0486	166

Length of Pole, 29 Feet

Sections: 21 feet, 7 feet, and 4 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7544	4	303	*fff*	336	220	7.24	3.29	158
7545	5	413	"	570	400	6.24	1.56	160
7546	6	544	"	889	600	5.00	.833	163
7547	7	685	"	1277	850	4.26	.501	165
7548	8	841	"	1759	1200	3.85	.321	166
7549	9	1006	"	2340	1600	3.46	.216	167
7550	10	1202	"	3130	2100	3.02	.144	166
7551	11	1377	"	3866	2600	2.78	.107	168
7552	12	1523	"	4587	3100	2.56	.0827	169
7553	13	1676	"	5574	3700	2.29	.0620	168
7554	4	391	*Eff*	447	300	7.59	2.53	151
7555	5	536	"	769	500	5.90	1.18	154
7556	6	746	"	1279	850	5.03	.592	155
7557	7	989	"	1959	1300	4.36	.335	157
7558	8	1152	"	2566	1700	3.81	.224	159
7559	9	1317	"	3254	2200	3.48	.158	161
7560	10	1500	"	4127	2800	3.11	.111	162
7561	11	1681	"	4991	3300	2.75	.0834	164
7562	12	1855	"	5936	4000	2.58	.0646	165
7563	13	2044	"	7234	4800	2.32	.0483	164
7564	4	410	*EEf*	447	300	7.44	2.48	157
7565	5	566	"	769	500	5.80	1.16	159
7566	6	787	"	1279	850	4.94	.581	161
7567	7	1057	"	1959	1300	4.26	.328	163
7568	8	1253	"	2566	1700	3.74	.220	166
7569	9	1421	"	3254	2200	3.41	.155	167
7570	10	1604	"	4127	2800	3.05	.109	167
7571	11	1781	"	4991	3300	2.72	.0824	168
7572	12	1956	"	5936	4000	2.56	.0639	169
7573	13	2154	"	7234	4800	2.29	.0477	168
7574	4	418	*EEE*	447	300	7.44	2.48	157
7575	5	577	"	769	500	5.75	1.15	160
7576	6	804	"	1279	850	4.94	.581	161
7577	7	1080	"	1959	1300	4.26	.328	164
7578	8	1292	"	2566	1700	3.74	.220	167
7579	9	1479	"	3254	2200	3.41	.155	168
7580	10	1663	"	4127	2800	3.05	.109	167
7581	11	1840	"	4991	3300	2.72	.0824	168
7582	12	2013	"	5936	4000	2.56	.0639	169
7583	13	2213	"	7234	4800	2.29	.0478	168

Length of Pole, 30 Feet

Sections: 21 feet and 10 feet 6 inches

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7584	3	220	*ff*	172	110	9.91	9.01	168
7585	4	306	"	321	220	8.40	3.82	164
7586	5	420	"	545	350	6.30	1.80	167
7587	6	552	"	849	550	5.29	.962	170
7588	7	693	"	1220	800	4.62	.578	172
7589	8	847	"	1681	1100	4.06	.369	173
7590	9	1012	"	2236	1500	3.72	.248	174
7591	10	1207	"	2991	2000	3.32	.166	174
7592	11	1383	"	3694	2500	3.08	.123	176
7593	12	1520	"	4383	2900	2.75	.0949	176
7594	13	1667	"	5326	3600	2.57	.0713	176
7595	3	277	*Ef*	223	150	10.6	7.09	162
7596	4	395	"	427	280	8.26	2.95	157
7597	5	544	"	735	500	6.85	1.37	160
7598	6	754	"	1222	800	5.50	.688	161
7599	7	998	"	1872	1200	4.67	.389	163
7600	8	1158	"	2452	1600	4.16	.260	165
7601	9	1323	"	3110	2100	3.82	.182	167
7602	10	1505	"	3944	2600	3.33	.128	168
7603	11	1687	"	4769	3200	3.08	.0963	171
7604	12	1852	"	5672	3800	2.82	.0743	171
7605	13	2035	"	6913	4500	2.51	.0557	171
7606	3	297	*EE*	223	150	10.4	6.96	168
7607	4	423	"	427	280	8.06	2.88	163
7608	5	588	"	735	500	6.70	1.34	167
7609	6	816	"	1222	800	5.38	.672	168
7610	7	1098	"	1872	1200	4.54	.378	171
7611	8	1310	"	2452	1600	4.05	.253	174
7612	9	1478	"	3110	2100	3.74	.178	175
7613	10	1660	"	3944	2600	3.28	.126	175
7614	11	1836	"	4769	3200	3.03	.0948	176
7615	12	2005	"	5672	3800	2.79	.0734	176
7616	13	2201	"	6913	4500	2.47	.0549	175

Length of Pole, 30 Feet

Sections: 18 feet 6 inches, 9 feet 6 inches, and 5 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7617	4	301	*fff*	321	220	8.98	4 08	156
7618	5	411	"	545	350	6.65	1.90	159
7619	6	544	"	849	550	5.50	1.00	164
7620	7	688	"	1220	800	4.78	.597	167
7621	8	847	"	1681	1100	4.18	.380	169
7622	9	1016	"	2236	1500	3.81	.254	170
7623	10	1214	"	2991	2000	3.42	.171	170
7624	11	1398	"	3694	2500	3.13	.125	173
7625	12	1553	"	4383	2900	2.79	.0963	174
7626	13	1709	"	5326	3600	2.61	.0724	173
7627	4	379	*Eff*	388	250	8.15	3.26	148
7628	5	520	"	723	500	7.45	1.49	150
7629	6	722	"	1222	800	5.96	.745	153
7630	7	957	"	1872	1200	5.02	.418	155
7631	8	1121	"	2452	1600	4.42	.276	159
7632	9	1290	"	3110	2100	4.03	.192	162
7633	10	1477	"	3944	2600	3.48	.134	163
7634	11	1666	"	4769	3200	3.20	.100	166
7635	12	1846	"	5672	3800	2.92	.0768	167
7636	13	2033	"	6913	4500	2.60	.0577	166
7637	4	404	*EEf*	427	280	8.65	3.09	154
7638	5	560	"	735	500	7.05	1.41	158
7639	6	778	"	1222	800	5.65	.706	160
7640	7	1048	"	1872	1200	4.72	.393	164
7641	8	1259	"	2452	1600	4.14	.259	169
7642	9	1431	"	3110	2100	3.82	.182	170
7643	10	1618	"	3944	2600	3.35	.129	171
7644	11	1801	"	4769	3200	3.08	.0964	172
7645	12	1983	"	5672	3800	2.83	.0744	173
7646	13	2183	"	6913	4500	2.52	.0559	172
7647	4	414	*EEE*	427	280	8.62	3.08	156
7648	5	573	"	735	500	7.05	1.41	159
7649	6	799	"	1222	800	5.64	.705	162
7650	7	1077	"	1872	1200	4.72	.393	165
7651	8	1307	"	2452	1600	4.14	.259	170
7652	9	1503	"	3110	2100	3.82	.182	172
7653	10	1692	"	3944	2600	3.33	.128	172
7654	11	1875	"	4769	3200	3.08	.0963	173
7655	12	2054	"	5672	3800	2.83	.0744	174
7656	13	2256	"	6913	4500	2.52	.0559	173

Length of Pole, 30 Feet

Sections: 19 feet, 7 feet, and 7 feet

Number	Size of butt	Weight	Thick-ness	Maxi-mum load P	Load for deflec-tion D L	Deflec-tion for load L D	Factor R	Factor m
7657	4	299	*fff*	321	220	8.93	4.06	152
7658	5	406	"	545	350	6.65	1.90	154
7659	6	539	"	849	550	5.50	1.00	159
7660	7	682	"	1220	800	4.77	.596	164
7661	8	841	"	1681	1100	4.17	.379	167
7662	9	1009	"	2236	1500	3.81	.254	169
7663	10	1207	"	2991	2000	3.40	.170	169
7664	11	1387	"	3694	2500	3.13	.125	171
7665	12	1545	"	4383	2900	2.79	.0962	173
7666	13	1704	"	5326	3600	2.60	.0723	173
7667	4	379	*Eff*	408	280	9.04	3.23	143
7668	5	518	"	735	500	7.45	1.49	144
7669	6	721	"	1222	800	5.92	.740	148
7670	7	957	"	1872	1200	4.98	.415	151
7671	8	1122	"	2452	1600	4.38	.274	156
7672	9	1290	"	3110	2100	4.01	.191	159
7673	10	1477	"	3944	2600	3.48	.134	161
7674	11	1663	"	4769	3200	3.18	.0994	164
7675	12	1845	"	5672	3800	2.91	.0765	167
7676	13	2036	"	6913	4500	2.58	.0574	166
7677	4	398	*EEf*	427	280	8.65	3.09	148
7678	5	548	"	735	500	7.15	1.43	148
7679	6	763	"	1222	800	5.67	.709	153
7680	7	1024	"	1872	1200	4.74	.395	157
7681	8	1224	"	2452	1600	4.16	.260	163
7682	9	1394	"	3110	2100	3.84	.183	166
7683	10	1580	"	3944	2600	3.35	.129	167
7684	11	1762	"	4769	3200	3.09	.0966	169
7685	12	1947	"	5672	3800	2.83	.0746	172
7686	13	2147	"	6913	4500	2.51	.0558	170
7687	4	411	*EEE*	427	280	8.60	3.07	151
7688	5	567	"	735	500	7.05	1.41	153
7689	6	792	"	1222	800	5.63	.704	157
7690	7	1066	"	1872	1200	4.70	.392	161
7691	8	1291	"	2452	1600	4.14	.259	167
7692	9	1495	"	3110	2100	3.82	.182	170
7693	10	1684	"	3944	2600	3.33	.128	171
7694	11	1866	"	4769	3200	3.08	.0962	172
7695	12	2046	"	5672	3800	2.82	.0743	173
7696	13	2248	"	6913	4500	2.51	.0557	173

Length of Pole, 30 Feet

Sections: 21 feet, 7 feet, and 5 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7697	4	309	*fff*	321	220	8.40	3.82	162
7698	5	420	"	545	350	6.30	1.80	164
7699	6	555	"	849	550	5.30	.964	167
7700	7	700	"	1220	800	4.62	.578	170
7701	8	860	"	1681	1100	4.07	.370	172
7702	9	1030	"	2236	1500	3.74	.249	173
7703	10	1231	"	2991	2000	3.32	.166	173
7704	11	1411	"	3694	2500	3.08	.123	175
7705	12	1563	"	4383	2900	2.75	.0949	175
7706	13	1722	"	5326	3600	2.57	.0713	175
7707	4	397	*Eff*	427	280	8.29	2.96	154
7708	5	544	"	735	500	6.85	1.37	156
7709	6	757	"	1222	800	5.52	.690	159
7710	7	1004	"	1872	1200	4.67	.389	160
7711	8	1171	"	2452	1600	4.16	.260	164
7712	9	1340	"	3110	2100	3.84	.183	166
7713	10	1529	"	3944	2600	3.33	.128	167
7714	11	1715	"	4769	3200	3.08	.0964	170
7715	12	1895	"	5672	3800	2.82	.0743	170
7716	13	2089	"	6913	4500	2.51	.0557	170
7717	4	416	*EEf*	427	280	8.09	2.89	160
7718	5	573	"	735	500	6.70	1.34	162
7719	6	798	"	1222	800	5.38	.673	164
7720	7	1071	"	1872	1200	4.55	.379	167
7721	8	1272	"	2452	1600	4.05	.253	171
7722	9	1444	"	3110	2100	3.74	.178	173
7723	10	1633	"	3944	2600	3.28	.126	173
7724	11	1815	"	4769	3200	3.04	.0949	175
7725	12	1997	"	5672	3800	2.79	.0734	174
7726	13	2200	"	6913	4500	2.48	.0550	175
7727	4	425	*EEE*	427	280	8.06	2.88	161
7728	5	587	"	735	500	6.70	1.34	164
7729	6	819	"	1222	800	5.38	.673	166
7730	7	1101	"	1872	1200	4.54	.378	169
7731	8	1320	"	2452	1600	4.05	.253	173
7732	9	1517	"	3110	2100	3.74	.178	174
7733	10	1707	"	3944	2600	3.28	.126	174
7734	11	1889	"	4769	3200	3.03	.0948	175
7735	12	2068	"	5672	3800	2.79	.0734	175
7736	13	2272	"	6913	4500	2.48	.0550	175

Length of Pole, 31 Feet

Sections: 18 feet 6 inches, 10 feet 6 inches, and 5 feet

Number	Size of butt	Weight	Thick-ness	Maxi-mum load P	Load for deflec-tion D L	Deflec-tion for load L D	Factor R	Factor m
7737	4	308	*fff*	307	200	9.46	4.73	163
7738	5	421	"	522	350	7.70	2.20	166
7739	6	559	"	813	550	6.38	1.16	170
7740	7	707	"	1168	800	5.49	.686	174
7741	8	871	"	1609	1100	4.80	.436	176
7742	9	1045	"	2141	1400	4.09	.292	178
7743	10	1248	"	2864	1900	3.72	.196	178
7744	11	1438	"	3537	2400	3.43	.143	181
7745	12	1599	"	4196	2800	3.08	.110	181
7746	13	1759	"	5100	3400	2.82	.0829	180
7747	4	386	*Eff*	352	220	8.38	3.81	154
7748	5	531	"	657	450	7.83	1.74	157
7749	6	736	"	1115	750	6.50	.866	159
7750	7	976	"	1738	1200	5.83	.486	161
7751	8	1145	"	2347	1600	5.12	.320	165
7752	9	1319	"	2977	2000	4.44	.222	168
7753	10	1511	"	3776	2500	3.88	.155	169
7754	11	1707	"	4566	3000	3.45	.115	173
7755	12	1891	"	5431	3600	3.18	.0884	174
7756	13	2083	"	6618	4500	2.99	.0665	173
7757	4	415	*EEf*	409	280	10.0	3.58	161
7758	5	575	"	704	450	7.38	1.64	164
7759	6	798	"	1170	800	6.51	.814	167
7760	7	1076	"	1792	1200	5.44	.453	171
7761	8	1297	"	2347	1600	4.75	.297	176
7762	9	1474	"	2977	2000	4.18	.209	178
7763	10	1666	"	3776	2500	3.68	.147	178
7764	11	1856	"	4566	3000	3.30	.110	180
7765	12	2044	"	5431	3600	3.07	.0852	181
7766	13	2249	"	6618	4500	2.88	.0640	180
7767	4	424	*EEE*	409	280	10.0	3.58	162
7768	5	588	"	704	450	7.34	1.63	166
7769	6	819	"	1170	800	6.51	.814	168
7770	7	1106	"	1792	1200	5.42	.452	172
7771	8	1345	"	2347	1600	4.75	.297	177
7772	9	1547	"	2977	2000	4.18	.209	179
7773	10	1740	"	3776	2500	3.68	.147	179
7774	11	1930	"	4566	3000	3.30	.110	181
7775	12	2115	"	5431	3600	3.07	.0852	182
7776	13	2321	"	6618	4500	2.88	.0640	180

Length of Pole, 31 Feet

Sections: 21 feet, 6 feet 6 inches, and 6 feet 6 inches

Number	Size of butt	Weight	Thick-ness	Maxi-mum load P	Load for deflec-tion D L	Deflec-tion for load L D	Factor R	Factor m
7777	4	314	*fff*	307	200	8.88	4.44	164
7778	5	426	"	522	350	7.32	2.09	165
7779	6	564	"	813	550	6.11	1.11	170
7780	7	712	"	1168	800	5.33	.666	174
7781	8	877	"	1609	1100	4.68	.425	177
7782	9	1051	"	2141	1400	3.99	.285	178
7783	10	1257	"	2864	1900	3.63	.191	178
7784	11	1441	"	3537	2400	3.36	.140	180
7785	12	1601	"	4196	2800	3.05	.109	182
7786	13	1765	"	5100	3400	2.77	.0816	182
7787	4	402	*Eff*	409	280	9.69	3.46	155
7788	5	550	"	704	450	7.25	1.61	156
7789	6	766	"	1170	800	6.43	.804	160
7790	7	1016	"	1792	1200	5.42	.452	163
7791	8	1188	"	2347	1600	4.82	.301	167
7792	9	1361	"	2977	2000	4.22	.211	170
7793	10	1555	"	3776	2500	3.70	.148	172
7794	11	1746	"	4566	3000	3.33	.111	175
7795	12	1933	"	5431	3600	3.07	.0854	176
7796	13	2133	"	6618	4500	2.88	.0641	176
7797	4	420	*EEf*	409	280	9.41	3.36	159
7798	5	577	"	704	450	7.02	1.56	161
7799	6	804	"	1170	800	6.26	.782	165
7800	7	1079	"	1792	1200	5.26	.438	169
7801	8	1282	"	2347	1600	4.66	.291	174
7802	9	1458	"	2977	2000	4.10	.205	176
7803	10	1651	"	3776	2500	3.63	.145	177
7804	11	1838	"	4566	3000	3.27	.109	180
7805	12	2027	"	5431	3600	3.03	.0841	180
7806	13	2236	"	6618	4500	2.83	.0629	180
7807	4	432	*EEE*	409	280	9.38	3.35	163
7808	5	595	"	704	450	7.02	1.56	164
7809	6	831	"	1170	800	6.22	.778	168
7810	7	1117	"	1792	1200	5.24	.437	172
7811	8	1344	"	2347	1600	4.64	.290	178
7812	9	1552	"	2977	2000	4.08	.204	180
7813	10	1747	"	3776	2500	3.60	.144	180
7814	11	1934	"	4566	3000	3.27	.109	182
7815	12	2120	"	5431	3600	3.02	.0840	182
7816	13	2330	"	6618	4500	2.83	.0629	182

Length of Pole, 32 Feet

Sections: 18 feet 6 inches, 9 feet 6 inches, and 7 feet

Number	Size of butt	Weight	Thick-ness	Maxi-mum load *P*	Load for deflec-tion *D* *L*	Deflec-tion for load *L* *D*	Factor *R*	Factor *m*
7817	4	312	*fff*	295	200	11.0	5.50	165
7818	5	426	"	500	350	8.93	2.55	167
7819	6	566	"	780	500	6.70	1.34	173
7820	7	718	"	1120	750	5.92	.789	178
7821	8	885	"	1544	1000	5.00	.500	181
7822	9	1063	"	2053	1400	4.68	.334	182
7823	10	1272	"	2747	1800	4.03	.224	183
7824	11	1466	"	3392	2300	3.75	.163	186
7825	12	1634	"	4025	2700	3.40	.126	188
7826	13	1801	"	4891	3300	3.12	.0946	187
7827	4	390	*Eff*	323	220	9.86	4.48	155
7828	5	535	"	602	400	8.16	2.04	156
7829	6	743	"	1022	700	7.07	1.01	160
7830	7	986	"	1593	1100	6.22	.565	164
7831	8	1159	"	2252	1500	5.55	.370	168
7832	9	1337	"	2856	1900	4.86	.256	172
7833	10	1534	"	3622	2400	4.30	.179	174
7834	11	1734	"	4380	2900	3.83	.132	178
7835	12	1927	"	5209	3500	3.54	.101	181
7836	13	2124	"	6348	4200	3.20	.0762	180
7837	4	416	*EEf*	392	250	10.5	4.19	160
7838	5	575	"	675	450	8.60	1.91	162
7839	6	800	"	1122	750	7.10	.946	167
7840	7	1077	"	1719	1100	5.75	.523	171
7841	8	1297	"	2252	1500	5.13	.342	178
7842	9	1478	"	2856	1900	4.54	.239	181
7843	10	1675	"	3622	2400	4.06	.169	181
7844	11	1869	"	4380	2900	3.65	.126	184
7845	12	2064	"	5209	3500	3.41	.0973	186
7846	13	2274	"	6348	4200	3.07	.0731	186
7847	4	429	*EEE*	392	250	10.4	4.17	164
7848	5	594	"	675	450	8.55	1.90	166
7849	6	829	"	1122	750	7.06	.941	170
7850	7	1118	"	1719	1100	5.73	.521	175
7851	8	1364	"	2252	1500	5.10	.340	182
7852	9	1579	"	2856	1900	4.52	.238	185
7853	10	1779	"	3622	2400	4.03	.168	185
7854	11	1973	"	4380	2900	3.65	.126	187
7855	12	2164	"	5209	3500	3.40	.0970	187
7856	13	2376	"	6348	4200	3.07	.0730	188

Length of Pole, 32 Feet

Sections: 21 feet, 7 feet, and 7 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7857	4	320	*fff*	295	200	10.2	5.11	168
7858	5	435	"	500	350	8.44	2.41	170
7859	6	577	"	780	500	6.35	1.27	175
7860	7	729	"	1120	750	5.71	.761	180
7861	8	898	"	1544	1000	4.85	.485	183
7862	9	1077	"	2053	1400	4.55	.325	185
7863	10	1288	"	2747	1800	3.92	.218	185
7864	11	1478	"	3392	2300	3.68	.160	187
7865	12	1644	"	4025	2700	3.35	.124	190
7866	13	1813	"	4891	3300	3.06	.0928	189
7867	4	409	*Eff*	392	250	10.1	4.02	159
7868	5	559	"	675	450	8.37	1.86	160
7869	6	778	"	1122	750	6.97	.929	164
7870	7	1033	"	1719	1100	5.74	.522	167
7871	8	1209	"	2252	1500	5.19	.346	172
7872	9	1387	"	2856	1900	4.60	.242	175
7873	10	1586	"	3622	2400	4.08	.170	177
7874	11	1783	"	4380	2900	3.68	.127	181
7875	12	1976	"	5209	3500	3.42	.0976	184
7876	13	2181	"	6348	4200	3.07	.0732	183
7877	4	428	*EEf*	392	250	9.70	3.88	164
7878	5	589	"	675	450	8.10	1.80	165
7879	6	820	"	1122	750	6.74	.898	169
7880	7	1100	"	1719	1100	5.52	.502	174
7881	8	1310	"	2252	1500	5.00	.333	179
7882	9	1491	"	2856	1900	4.45	.234	182
7883	10	1690	"	3622	2400	3.96	.165	183
7884	11	1882	"	4380	2900	3.60	.124	185
7885	12	2078	"	5209	3500	3.35	.0957	188
7886	13	2291	"	6348	4200	3.01	.0717	187
7887	4	441	*EEE*	392	250	9.65	3.86	167
7888	5	608	"	675	450	8.06	1.79	169
7889	6	849	"	1122	750	6.70	.893	173
7890	7	1142	"	1719	1100	5.49	.499	178
7891	8	1378	"	2252	1500	4.97	.331	184
7892	9	1593	"	2856	1900	4.43	.233	186
7893	10	1793	"	3622	2400	3.94	.164	187
7894	11	1986	"	4380	2900	3.60	.124	188
7895	12	2177	"	5209	3500	3.34	.0955	189
7896	13	2393	"	6348	4200	3.01	.0716	189

Length of Pole, 32 Feet

Sections: 21 feet, 10 feet, and 4 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7897	4	326	*fff*	295	200	10.14	5.07	175
7898	5	445	"	500	350	8.33	2.38	178
7899	6	588	"	780	500	6.30	1.26	182
7900	7	742	"	1120	750	5.67	.756	185
7901	8	912	"	1544	1000	4.83	.483	186
7902	9	1092	"	2053	1400	4.54	.324	188
7903	10	1304	"	2747	1800	3.91	.217	187
7904	11	1498	"	3392	2300	3.66	.159	190
7905	12	1660	"	4025	2700	3.32	.123	191
7906	13	1825	"	4891	3300	3.06	.0927	191
7907	4	414	*Eff*	392	250	9.95	3.98	166
7908	5	569	"	675	450	8.24	1.83	169
7909	6	790	"	1122	750	6.89	.918	171
7910	7	1046	"	1719	1100	5.69	.517	173
7911	8	1222	"	2252	1500	5.16	.344	176
7912	9	1403	"	2856	1900	4.56	.240	179
7913	10	1602	"	3622	2400	4.06	.169	180
7914	11	1803	"	4380	2900	3.65	.126	184
7915	12	1991	"	5209	3500	3.41	.0974	185
7916	13	2193	"	6348	4200	3.07	.0731	185
7917	4	441	*EEf*	392	250	9.58	3.83	174
7918	5	611	"	675	450	7.97	1.77	177
7919	6	849	"	1122	750	6.64	.885	180
7920	7	1142	"	1719	1100	5.46	.496	183
7921	8	1367	"	2252	1500	4.95	.330	187
7922	9	1551	"	2856	1900	4.41	.232	188
7923	10	1750	"	3622	2400	3.94	.164	189
7924	11	1945	"	4380	2900	3.57	.123	190
7925	12	2136	"	5209	3500	3.34	.0953	191
7926	13	2351	"	6348	4200	3.00	.0715	191
7927	4	449	*EEE*	392	250	9.58	3.83	174
7928	5	622	"	675	450	7.97	1.77	178
7929	6	866	"	1122	750	6.64	.885	180
7930	7	1166	"	1719	1100	5.46	.496	183
7931	8	1406	"	2252	1500	4.95	.330	188
7932	9	1609	"	2856	1900	4.41	.232	189
7933	10	1809	"	3622	2400	3.94	.164	189
7934	11	2004	"	4380	2900	3.57	.123	190
7935	12	2193	"	5209	3500	3.34	.0953	191
7936	13	2409	"	6348	4200	3.00	.0715	191

Length of Pole, 33 Feet

Sections: 18 feet 6 inches, 10 feet 6 inches, and 7 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7937	4	320	*fff*	283	190	12.0	6.31	172
7938	5	437	"	481	300	8.73	2.91	174
7939	6	580	"	749	500	7.60	1.52	180
7940	7	737	"	1076	700	6.28	.897	185
7941	8	909	"	1483	1000	5.68	.568	188
7942	9	1092	"	1973	1300	4.93	.379	190
7943	10	1306	"	2639	1800	4.57	.254	190
7944	11	1506	"	3259	2200	4.07	.185	193
7945	12	1680	"	3867	2600	3.69	.142	196
7946	13	1850	"	4699	3100	3.32	.107	195
7947	4	398	*Eff*	298	200	10.3	5.17	162
7948	5	546	"	556	350	8.23	2.35	163
7949	6	758	"	943	650	7.54	1.16	167
7950	7	1005	"	1470	1000	6.49	.649	170
7951	8	1183	"	2112	1400	5.94	.424	175
7952	9	1366	"	2744	1800	5.26	.292	179
7953	10	1568	"	3480	2300	4.69	.204	181
7954	11	1775	"	4208	2800	4.20	.150	185
7955	12	1972	"	5005	3300	3.80	.115	188
7956	13	2174	"	6099	4000	3.47	.0868	187
7957	4	426	*EEf*	377	250	12.0	4.80	167
7958	5	590	"	649	450	9.81	2.18	169
7959	6	820	"	1078	700	7.56	1.08	174
7960	7	1106	"	1652	1100	6.55	.595	179
7961	8	1335	"	2163	1400	5.43	.388	185
7962	9	1521	"	2744	1800	4.88	.271	188
7963	10	1724	"	3480	2300	4.39	.191	189
7964	11	1924	"	4208	2800	4.00	.143	192
7965	12	2125	"	5005	3300	3.63	.110	194
7966	13	2340	"	6099	4000	3.31	.0828	193
7967	4	439	*EEE*	377	250	12.0	4.78	170
7968	5	609	"	649	450	9.77	2.17	173
7969	6	849	"	1078	700	7.49	1.07	177
7970	7	1147	"	1652	1100	6.52	.593	182
7971	8	1402	"	2163	1400	5.40	.386	189
7972	9	1623	"	2744	1800	4.86	.270	192
7973	10	1827	"	3480	2300	4.39	.191	192
7974	11	2027	"	4208	2800	4.00	.143	194
7975	12	2224	"	5005	3300	3.63	.110	195
7976	13	2441	"	6099	4000	3.31	.0827	195

Length of Pole, 33 Feet

Sections: 21 feet, 10 feet, and 5 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
7977	4	332	fff	283	190	11.0	5.80	179
7978	5	453	"	481	300	8.16	2.72	183
7979	6	599	"	749	500	7.20	1.44	187
7980	7	757	"	1076	700	6.01	.859	191
7981	8	931	"	1483	1000	5.48	.548	193
7982	9	1115	"	1973	1300	4.77	.367	194
7983	10	1333	"	2639	1800	4.43	.246	194
7984	11	1532	"	3259	2200	3.98	.181	197
7985	12	1700	"	3867	2600	3.64	.140	198
7986	13	1871	"	4699	3100	3.26	.105	198
7987	4	420	Eff	369	250	11.5	4.59	169
7988	5	576	"	649	450	9.50	2.11	173
7989	6	801	"	1078	700	7.35	1.05	175
7990	7	1061	"	1652	1100	6.52	.593	178
7991	8	1241	"	2163	1400	5.52	.394	182
7992	9	1426	"	2744	1800	4.93	.274	184
7993	10	1631	"	3480	2300	4.44	.193	186
7994	11	1837	"	4208	2800	4.03	.144	190
7995	12	2032	"	5005	3300	3.66	.111	191
7996	13	2238	"	6099	4000	3.32	.0830	191
7997	4	447	EEf	377	250	11.0	4.39	177
7998	5	618	"	649	450	9.09	2.02	181
7999	6	860	"	1078	700	7.07	1.01	184
8000	7	1157	"	1652	1100	6.22	.565	188
8001	8	1386	"	2163	1400	5.24	.374	193
8002	9	1574	"	2744	1800	4.73	.263	194
8003	10	1779	"	3480	2300	4.28	.186	195
8004	11	1979	"	4208	2800	3.92	.140	196
8005	12	2177	"	5005	3300	3.56	.108	197
8006	13	2396	"	6099	4000	3.24	.0809	196
8007	4	456	EEE	377	250	11.0	4.38	178
8008	5	632	"	649	450	9.09	2.02	182
8009	6	881	"	1078	700	7.07	1.01	185
8010	7	1187	"	1652	1100	6.20	.564	189
8011	8	1434	"	2163	1400	5.24	.374	194
8012	9	1647	"	2744	1800	4.73	.263	195
8013	10	1853	"	3480	2300	4.28	.186	196
8014	11	2053	"	4208	2800	3.89	.139	197
8015	12	2248	"	5005	3300	3.56	.108	198
8016	13	2469	"	6099	4000	3.23	.0808	197

Length of Pole, 34 Feet

Sections: 19 feet 6 inches, 10 feet 6 inches, and 7 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
8017	4	331	*fff*	273	180	12.5	6.95	179
8018	5	451	"	462	300	9.66	3.22	182
8019	6	599	"	721	500	8.45	1.69	188
8020	7	760	"	1036	700	6.98	.997	193
8021	8	938	"	1427	950	6.01	.633	196
8022	9	1126	"	1898	1300	5.49	.422	198
8023	10	1346	"	2539	1700	4.81	.283	198
8024	11	1552	"	3136	2100	4.33	.206	201
8025	12	1730	"	3721	2500	3.98	.159	204
8026	13	1905	"	4522	3000	3.60	.120	203
8027	4	413	*Eff*	298	200	11.3	5.66	169
8028	5	566	"	556	350	9.03	2.58	170
8029	6	787	"	943	650	8.32	1.28	174
8030	7	1043	"	1470	1000	7.14	.714	178
8031	8	1226	"	2082	1400	6.57	.469	183
8032	9	1415	"	2640	1800	5.83	.324	187
8033	10	1623	"	3348	2200	4.97	.226	189
8034	11	1835	"	4049	2700	4.51	.167	193
8035	12	2038	"	4816	3200	4.10	.128	195
8036	13	2246	"	5869	3900	3.76	.0965	195
8037	4	441	*EEf*	362	250	13.2	5.29	175
8038	5	610	"	624	400	9.64	2.41	177
8039	6	849	"	1038	700	8.33	1.19	181
8040	7	1144	"	1589	1100	7.27	.661	187
8041	8	1378	"	2082	1400	6.05	.432	193
8042	9	1570	"	2640	1800	5.44	.302	196
8043	10	1778	"	3348	2200	4.69	.213	197
8044	11	1984	"	4049	2700	4.32	.160	200
8045	12	2190	"	4816	3200	3.94	.123	201
8046	13	2412	"	5869	3900	3.60	.0924	201
8047	4	454	*EEE*	362	250	13.2	5.27	178
8048	5	629	"	624	400	9.60	2.40	181
8049	6	878	"	1038	700	8.33	1.19	185
8050	7	1185	"	1589	1100	7.24	.658	190
8051	8	1446	"	2082	1400	6.02	.430	197
8052	9	1671	"	2640	1800	5.42	.301	200
8053	10	1882	"	3348	2200	4.69	.213	200
8054	11	2087	"	4049	2700	4.29	.159	203
8055	12	2289	"	4816	3200	3.94	.123	203
8056	13	2513	"	5869	3900	3.60	.0923	203

Number	of butt	Weight	Thick-ness	load	deflec-tion D	load L	Factor	Factor
				P	L	D	R	m
8057	4	336	*fff*	273	180	12.0	6.64	[illegible]
8058	5	459	"	462	300	9.30	3.10	185
8059	6	608	"	721	500	8.20	1.64	190
8060	7	769	"	1036	700	6.82	.974	195
8061	8	947	"	1427	950	5.89	620	198
8062	9	1136	"	1898	1300	5.40	415	200
[illegible]	10	1359	"	2539	1700	4.73	.278	200
8064	11	1563	"	3136	2100	4.28	204	202
8065	12	1738	"	3721	2500	3.93	157	[illegible]
8066	13	1914	"	4522	3000	3.54	.118	204
8067	4	425	*Eff*	337	220	11.6	5.29	172
8068	5	582	"	624	[illegible]	9.72	2.43	174
8069	6	810	"	1038	700	8.47	1.21	178
8070	7	1073	"	1589	1100	7.47	.679	181
8071	8	1258	"	2082	1400	6.29	449	[illegible]
8072	9	1447	"	2640	1800	5.62	312	189
8073	10	1657	"	3348	2200	4.82	219	191
8074	11	1867	"	4049	2700	4.40	163	195
8075	12	2070	"	4816	3200	4.00	125	197
8076	13	2282	"	5869	3900	3.67	.0940	196
8077	4	451	*EEf*	362	250	12.6	5.03	178
8078	5	622	"	624	400	9.24	2.31	181
8079	6	866	"	1038	700	8.05	1.15	[illegible]
8080	7	1165	"	1589	1100	7.06	642	190
8081	8	1396	"	2082	1400	5.94	.424	196
8082	9	[illegible]	"	2640	1800	5.36	.298	198
8083	10	1797	"	3348	2200	4.62	.210	199
8084	11	2002	"	4049	2700	4.27	.158	201
8085	12	2208	"	4816	3200	3.90	122	203
[illegible]	13	2432	"	5869	3900	3.56	0913	203
8087	4	463	*EEE*	362	250	12.6	5.02	181
8088	5	640	"	624	400	9.20	2.30	184
8089	6	893	"	1038	700	8.05	1.15	188
8090	7	1203	"	1589	1100	7.05	.641	193
8091	8	1458	"	2082	1400	5.92	423	199
8092	9	1682	"	2640	1800	5.35	.297	207
8093	10	1894	"	3348	2200	4.60	209	202
8094	11	2098	"	4049	2700	4.24	.157	204
8095	12	2300	"	4816	3200	3.90	122	205
8096	13	2526	"	5869	3900	3.56	.0912	204

Length of Pole, 35 Feet

Sections: 18 feet 6 inches, 10 feet, and 9 feet 6 inches

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
8097	4	331	*fff*	258	170	14.2	8.33	179
8098	5	450	"	446	300	11.5	3.84	180
8099	6	600	"	695	450	8.91	1.98	187
8100	7	764	"	998	650	7.54	1.16	194
8101	8	945	"	1375	900	6.57	.730	199
8102	9	1137	"	1829	1200	5.82	.485	201
8103	10	1360	"	2447	1600	5.20	.325	202
8104	11	1571	"	3022	2000	4.70	.235	205
8105	12	1758	"	3586	2400	4.34	.181	209
8106	13	1939	"	4358	2900	3.94	.136	208
8107	4	408	*Eff*	258	170	11.8	6.96	168
8108	5	559	"	482	300	9.48	3.16	168
8109	6	778	"	817	550	8.53	1.55	174
8110	7	1032	"	1274	850	7.29	.858	178
8111	8	1218	"	1830	1200	6.67	.556	185
8112	9	1410	"	2522	1700	6.46	.380	189
8113	10	1623	"	3227	2200	5.83	.265	192
8114	11	1839	"	3902	2600	5.04	.194	197
8115	12	2051	"	4641	3100	4.59	.148	200
8116	13	2263	"	5656	3800	4.26	.112	199
8117	4	436	*EEf*	335	220	14.1	6.42	172
8118	5	601	"	597	400	11.7	2.92	172
8119	6	837	"	1000	650	9.30	1.43	178
8120	7	1128	"	1532	1000	7.81	.781	184
8121	8	1363	"	2006	1300	6.53	.502	192
8122	9	1558	"	2544	1700	5.93	.349	196
8123	10	1771	"	3227	2200	5.41	.246	198
8124	11	1981	"	3902	2600	4.76	.183	202
8125	12	2196	"	4641	3100	4.37	.141	204
8126	13	2421	"	5656	3800	4.03	.106	204
8127	4	453	*EEE*	335	220	13.9	6.33	177
8128	5	627	"	601	400	11.5	2.87	179
8129	6	877	"	1000	650	9.17	1.41	185
8130	7	1184	"	1532	1000	7.70	.770	191
8131	8	1455	"	2006	1300	6.44	.495	199
8132	9	1696	"	2544	1700	5.87	.345	204
8133	10	1911	"	3227	2200	5.35	.243	205
8134	11	2122	"	3902	2600	4.71	.181	208
8135	12	2331	"	4641	3100	4.34	.140	208
8136	13	2559	"	5656	3800	3.99	.105	208

Length of Pole, 35 Feet

Sections: 21 feet, 10 feet, and 7 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
8137	4	343	*fff*	263	180	13.6	7.54	187
8138	5	468	"	446	300	10.5	3.51	190
8139	6	621	"	695	450	8.33	1.85	196
8140	7	786	"	998	650	7.15	1.10	201
8141	8	969	"	1375	900	6.28	.698	204
8142	9	1162	"	1829	1200	5.60	.467	206
8143	10	1390	"	2447	1600	5.00	.313	206
8144	11	1600	"	3022	2000	4.58	.229	210
8145	12	1781	"	3586	2400	4.25	.177	213
8146	13	1962	"	4358	2900	3.86	.133	211
8147	4	431	*Eff*	310	200	12.1	6.06	176
8148	5	592	"	578	400	11.1	2.77	178
8149	6	822	"	981	650	8.97	1.38	182
8150	7	1090	"	1529	1000	7.73	.773	186
8151	8	1279	"	2006	1300	6.63	.510	191
8152	9	1473	"	2544	1700	6.00	.353	195
8153	10	1688	"	3227	2200	5.43	.247	197
8154	11	1904	"	3902	2600	4.76	.183	201
8155	12	2113	"	4641	3100	4.37	.141	204
8156	13	2329	"	5656	3800	4.03	.106	203
8157	4	459	*EEf*	349	220	12.6	5.73	183
8158	5	634	"	601	400	10.5	2.62	185
8159	6	881	"	1000	650	8.52	1.31	190
8160	7	1186	"	1532	1000	7.26	.726	195
8161	8	1424	"	2006	1300	6.20	.477	202
8162	9	1621	"	2544	1700	5.70	.335	204
8163	10	1836	"	3227	2200	5.19	.236	205
8164	11	2046	"	3902	2600	4.60	.177	208
8165	12	2258	"	4641	3100	4.25	.137	211
8166	13	2487	"	5656	3800	3.91	.103	209
8167	4	472	*EEE*	349	220	12.6	5.71	186
8168	5	653	"	601	400	10.4	2.61	189
8169	6	911	"	1000	650	8.45	1.30	194
8170	7	1228	"	1532	1000	7.23	.723	198
8171	8	1492	"	2006	1300	6.18	.475	205
8172	9	1723	"	2544	1700	5.66	.333	208
8173	10	1940	"	3227	2200	5.17	.235	209
8174	11	2150	"	3902	2600	4.60	.177	211
8175	12	2357	"	4641	3100	4.22	.136	212
8176	13	2589	"	5656	3800	3.88	.102	211

Length of Pole, 35 Feet

Sections: 18 feet 6 inches, 9 feet 6 inches, 6 feet 6 inches, and 5 feet

Number	Size of butt	Weight	Thick-ness	Maxi-mum load *P*	Load for deflec-tion *D* *L*	Deflec-tion for load *L* *D*	Factor *R*	Factor *m*
8177	5	451	*ffff*	446	300	11.6	3.88	175
8178	6	598	"	695	450	9.00	2.00	183
8179	7	764	"	998	650	7.54	1.16	191
8180	8	949	"	1375	900	6.60	.733	196
8181	9	1147	"	1829	1200	5.84	.487	199
8182	10	1375	"	2447	1600	5.22	.326	200
8183	11	1592	"	3022	2000	4.72	.236	204
8184	12	1784	"	3586	2400	4.34	.181	208
8185	13	1980	"	4358	2900	3.94	.136	207
8186	5	560	*Efff*	482	300	9.60	3.20	164
8187	6	776	"	817	550	8.64	1.57	168
8188	7	1032	"	1274	850	7.34	.864	174
8189	8	1223	"	1830	1200	6.71	.559	182
8190	9	1421	"	2522	1700	6.49	.382	187
8191	10	1638	"	3227	2200	5.83	.265	190
8192	11	1860	"	3902	2600	5.04	.194	195
8193	12	2076	"	4641	3100	4.59	.148	198
8194	13	2304	"	5656	3900	4.37	.112	198
8195	5	600	*EEff*	554	350	10.4	2.96	166
8196	6	832	"	1000	650	9.43	1.45	172
8197	7	1124	"	1532	1000	7.89	.789	179
8198	8	1360	"	2006	1300	6.58	.506	188
8199	9	1561	"	2544	1700	5.98	.352	193
8200	10	1778	"	3227	2200	5.43	.247	195
8201	11	1995	"	3902	2600	4.78	.184	200
8202	12	2214	"	4641	3100	4.37	.141	203
8203	13	2454	"	5656	3900	4.13	.106	203
8204	5	618	*EEEf*	601	400	11.6	2.90	172
8205	6	859	"	1000	650	9.23	1.42	178
8206	7	1162	"	1532	1000	7.75	.775	185
8207	8	1423	"	2006	1300	6.47	.498	195
8208	9	1655	"	2544	1700	5.88	.346	201
8209	10	1874	"	3227	2200	5.37	.244	202
8210	11	2091	"	3902	2600	4.73	.182	205
8211	12	2306	"	4641	3100	4.34	.140	207
8212	13	2548	"	5656	3900	4.10	.105	206
8213	5	627	*EEEE*	601	400	11.6	2.90	174
8214	6	873	"	1000	650	9.23	1.42	180
8215	7	1183	"	1532	1000	7.75	.775	187
8216	8	1452	"	2006	1300	6.46	.497	196
8217	9	1703	"	2544	1700	5.88	.346	202
8218	10	1947	"	3227	2200	5.37	.244	203
8219	11	2165	"	3902	2600	4.73	.182	206
8220	12	2380	"	4641	3100	4.34	.140	207
8221	13	2619	"	5656	3900	4.10	.105	207

Length of Pole, 36 Feet

Sections: 18 feet 6 inches, 10 feet 6 inches, and 10 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
8222	4	337	*fff*	242	160	15.1	9.45	185
8223	5	459	"	430	280	12.2	4.35	185
8224	6	613	"	670	450	10.1	2.24	193
8225	7	780	"	963	650	8.45	1.30	201
8226	8	966	"	1327	900	7.38	.820	205
8227	9	1162	"	1765	1200	6.53	.544	208
8228	10	1391	"	2361	1600	5.82	.364	209
8229	11	1608	"	2916	1900	5.00	.263	212
8230	12	1801	"	3460	2300	4.65	.202	216
8231	13	1987	"	4205	2800	4.26	.152	215
8232	4	415	*Eff*	242	160	12.7	7.95	174
8233	5	568	"	452	300	10.8	3.60	174
8234	6	790	"	766	500	8.85	1.77	179
8235	7	1049	"	1195	800	7.79	.974	184
8236	8	1240	"	1716	1100	6.92	.629	191
8237	9	1436	"	2364	1600	6.88	.430	196
8238	10	1654	"	3113	2100	6.26	.298	198
8239	11	1876	"	3765	2500	5.45	.218	203
8240	12	2094	"	4478	3000	4.98	.166	206
8241	13	2311	"	5457	3600	4.50	.125	205
8242	4	444	*EEf*	314	200	14.6	7.29	177
8243	5	613	"	554	350	11.6	3.31	177
8244	6	852	"	965	650	10.5	1.62	183
8245	7	1149	"	1478	1000	8.81	.881	190
8246	8	1392	"	1935	1300	7.33	.564	198
8247	9	1592	"	2455	1600	6.27	.392	202
8248	10	1809	"	3113	2100	5.80	.276	205
8249	11	2025	"	3765	2500	5.13	.205	208
8250	12	2246	"	4478	3000	4.71	.157	212
8251	13	2477	"	5457	3600	4.25	.118	210
8252	4	462	*EEE*	314	200	14.4	7.19	183
8253	5	640	"	580	400	13.0	3.25	184
8254	6	894	"	965	650	10.3	1.59	191
8255	7	1208	"	1478	1000	8.67	.867	197
8256	8	1488	"	1935	1300	7.23	.556	206
8257	9	1737	"	2455	1600	6.18	.386	211
8258	10	1957	"	3113	2100	5.73	.273	212
8259	11	2173	"	3765	2500	5.08	.203	214
8260	12	2388	"	4478	3000	4.68	.156	216
8261	13	2622	"	5457	3600	4.25	.118	214

Length of Pole, 36 Feet

Sections: 19 feet, 9 feet 6 inches, 7 feet, and 5 feet

Number	Size of butt	Weight	Thick-ness	Maxi-mum load P	Load for deflec-tion D L	Deflec-tion for load L D	Factor R	Factor m
8262	5	462	*ffff*	430	280	12.1	4.33	181
8263	6	613	"	670	450	10.0	2.23	189
8264	7	783	"	963	650	8.45	1.30	197
8265	8	973	"	1327	900	7.34	.816	203
8266	9	1175	"	1765	1200	6.50	.542	206
8267	10	1409	"	2361	1600	5.81	.363	207
8268	11	1631	"	2916	1900	5.00	.263	211
8269	12	1829	"	3460	2300	4.65	.202	215
8270	13	2030	"	4205	2800	4.26	.152	214
8271	5	574	*Efff*	466	300	10.7	3.57	169
8272	6	796	"	791	550	9.63	1.75	174
8273	7	1059	"	1233	800	7.70	.963	180
8274	8	1254	"	1771	1200	7.46	.622	188
8275	9	1457	"	2440	1600	6.80	.425	194
8276	10	1679	"	3113	2100	6.20	.295	197
8277	11	1907	"	3765	2500	5.40	.216	201
8278	12	2129	"	4478	3000	4.95	.165	206
8279	13	2363	"	5457	3600	4.46	.124	204
8280	5	614	*EEff*	517	350	11.6	3.31	171
8281	6	852	"	964	650	10.5	1.62	177
8282	7	1150	"	1478	1000	8.80	.880	185
8283	8	1392	"	1935	1300	7.35	.565	194
8284	9	1597	"	2455	1600	6.27	.392	199
8285	10	1820	"	3113	2100	5.80	.276	202
8286	11	2042	"	3765	2500	5.13	.205	206
8287	12	2267	"	4478	3000	4.71	.157	210
8288	13	2513	"	5457	3600	4.25	.118	209
8289	5	633	*EEEf*	580	400	13.0	3.24	178
8290	6	881	"	965	650	10.3	1.58	184
8291	7	1191	"	1478	1000	8.64	.864	192
8292	8	1459	"	1935	1300	7.22	.555	202
8293	9	1699	"	2455	1600	6.16	.385	208
8294	10	1923	"	3113	2100	5 69	.271	209
8295	11	2146	"	3765	2500	5.05	.202	212
8296	12	2366	"	4478	3000	4.68	.156	214
8297	13	2614	"	5457	3600	4.21	.117	213
8298	5	642	*EEEE*	580	400	12.9	3.23	180
8299	6	895	"	965	650	10.3	1.58	186
8300	7	1212	"	1478	1000	8.64	.864	193
8301	8	1488	"	1935	1300	7.20	.554	203
8302	9	1747	"	2455	1600	6.16	.385	209
8303	10	1996	"	3113	2100	5.69	.271	210
8304	11	2220	"	3765	2500	5.05	.202	213
8305	12	2440	"	4478	3000	4.68	.156	215
8306	13	2685	"	5457	3600	4.21	.117	214

Length of Pole, 37 Feet

Sections: 19 feet, 10 feet 6 inches, and 10 feet 6 inches

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
8307	4	346	*fff*	235	160	16.8	10.5	191
8308	5	470	"	415	280	13.6	4.84	191
8309	6	628	"	648	450	11.2	2.49	200
8310	7	799	"	930	600	8.70	1.45	207
8311	8	990	"	1282	850	7.73	.909	212
8312	9	1191	"	1705	1100	6.64	.604	215
8313	10	1426	"	2281	1500	6.06	.404	216
8314	11	1648	"	2817	1900	5.55	.292	219
8315	12	1846	"	3343	2200	4.93	.224	223
8316	13	2037	"	4062	2700	4.56	.169	222
8317	4	425	*Eff*	235	160	14.1	8.82	180
8318	5	582	"	438	300	12.0	4.00	179
8319	6	810	"	743	500	9.80	1.96	185
8320	7	1075	"	1158	750	8.10	1.08	190
8321	8	1271	"	1664	1100	7.68	.698	197
8322	9	1472	"	2292	1500	7.14	.476	202
8323	10	1696	"	3008	2000	6.62	.331	205
8324	11	1923	"	3637	2400	5.81	.242	209
8325	12	2147	"	4326	2900	5.34	.184	213
8326	13	2370	"	5272	3500	4.87	.139	213
8327	4	454	*EEf*	305	200	16.2	8.11	183
8328	5	627	"	517	350	12.9	3.68	182
8329	6	872	"	932	600	10.8	1.80	189
8330	7	1176	"	1428	950	9.30	.979	195
8331	8	1423	"	1870	1200	7.54	.628	204
8332	9	1628	"	2372	1600	6.98	.436	209
8333	10	1851	"	3008	2000	6.12	.306	211
8334	11	2072	"	3637	2400	5.47	.228	215
8335	12	2299	"	4326	2900	5.08	.175	218
8336	13	2535	"	5272	3500	4.59	.131	218
8337	4	474	*EEE*	305	200	16.0	7.98	189
8338	5	655	"	560	350	12.6	3.61	190
8339	6	916	"	932	600	10.6	1.76	197
8340	7	1238	"	1428	950	9.15	.963	203
8341	8	1524	"	1870	1200	7.40	.617	213
8342	9	1780	"	2372	1600	6.86	.429	218
8343	10	2006	"	3008	2000	6.04	.302	219
8344	11	2228	"	3637	2400	5.40	.225	221
8345	12	2448	"	4326	2900	5.02	.173	223
8346	13	2688	"	5272	3500	4.55	.130	223

Length of Pole, 38 Feet

Sections: 20 feet, 10 feet 6 inches, and 10 feet 6 inches

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
8347	4	356	*fff*	235	160	18.2	11.4	198
8348	5	485	"	402	280	14.7	5.25	198
8349	6	647	"	626	400	10.8	2.71	207
8350	7	823	"	900	600	9.48	1.58	215
8351	8	1018	"	1240	850	8.46	.995	220
8352	9	1225	"	1649	1100	7.28	.662	223
8353	10	1466	"	2206	1500	6.65	.443	224
8354	11	1693	"	2725	1800	5.78	.321	227
8355	12	1896	"	3233	2200	5.41	.246	231
8356	13	2092	"	3929	2600	4.84	.186	230
8357	4	440	*Eff*	235	160	15.2	9.47	186
8358	5	603	"	438	300	12.9	4.31	186
8359	6	839	"	743	500	10.6	2.11	192
8360	7	1113	"	1158	750	8.78	1.17	197
8361	8	1314	"	1664	1100	8.33	.757	204
8362	9	1521	"	2292	1500	7.77	.518	210
8363	10	1750	"	2909	1900	6.84	.360	212
8364	11	1983	"	3518	2300	6.07	.264	217
8365	12	2212	"	4184	2800	5.66	.202	221
8366	13	2442	"	5099	3400	5.17	.152	220
8367	4	469	*EEf*	305	200	17.5	8.76	190
8368	5	647	"	517	350	14.0	3.99	189
8369	6	901	"	902	600	11.7	1.95	196
8370	7	1214	"	1381	900	9.63	1.07	202
8371	8	1467	"	1808	1200	8.23	.686	212
8372	9	1676	"	2294	1500	7.16	.477	217
8373	10	1906	"	2909	1900	6.38	.336	219
8374	11	2132	"	3518	2300	5.75	.250	223
8375	12	2364	"	4184	2800	5.38	.192	226
8376	13	2608	"	5099	3400	4.90	.144	226
8377	4	489	*EEE*	305	200	17.3	8.63	196
8378	5	676	"	542	350	13.7	3.91	197
8379	6	945	"	902	600	11.5	1.92	204
8380	7	1276	"	1381	900	9.45	1.05	211
8381	8	1567	"	1808	1200	8.11	.676	221
8382	9	1829	"	2294	1500	7.05	.470	226
8383	10	2061	"	2909	1900	6.29	.331	227
8384	11	2288	"	3518	2300	5.68	.247	229
8385	12	2514	"	4184	2800	5.32	.190	231
8386	13	2760	"	5099	3400	4.86	.143	231

Length of Pole, 39 Feet

Sections: 21 feet, 10 feet 6 inches, and 10 feet 6 inches

Number	Size of butt	Weight	Thick-ness	Maxi-mum load P	Load for deflec-tion D L	Deflec-tion for load L D	Factor R	Factor m
8387	4	367	*fff*	229	150	18.5	12.3	205
8388	5	500	"	389	250	14.2	5.69	206
8389	6	666	"	607	400	11.8	2.94	215
8390	7	846	"	871	600	10.3	1.72	223
8391	8	1047	"	1201	800	8.72	1.09	228
8392	9	1259	"	1597	1100	7.95	.723	231
8393	10	1507	"	2136	1400	6.78	.484	232
8394	11	1739	"	2638	1800	6.34	.352	235
8395	12	1946	"	3130	2100	5.67	.270	239
8396	13	2146	"	3804	2500	5.08	.203	238
8397	4	455	*Eff*	235	160	16.3	10.2	193
8398	5	623	"	438	300	13.9	4.63	192
8399	6	867	"	743	500	11.4	2.28	199
8400	7	1151	"	1158	750	9.45	1.26	204
8401	8	1358	"	1664	1100	9.02	.820	212
8402	9	1570	"	2221	1500	8.43	.562	217
8403	10	1805	"	2817	1900	7.45	.392	220
8404	11	2043	"	3406	2300	6.60	.287	225
8405	12	2278	"	4052	2700	5.94	.220	229
8406	13	2514	"	4937	3300	5.48	.166	228
8407	4	484	*EEf*	305	200	18.9	9.45	197
8408	5	668	"	517	350	15.1	4.31	196
8409	6	929	"	873	600	12.7	2.12	203
8410	7	1252	"	1337	900	10.4	1.16	211
8411	8	1510	"	1751	1200	8.99	.749	220
8412	9	1725	"	2221	1500	7.83	.522	225
8413	10	1960	"	2817	1900	6.97	.367	227
8414	11	2192	"	3406	2300	6.28	.273	231
8415	12	2430	"	4052	2700	5.67	.210	234
8416	13	2680	"	4937	3300	5.21	.158	234
8417	4	504	*EEE*	305	200	18.6	9.32	203
8418	5	696	"	525	350	14.8	4.24	204
8419	6	973	"	873	600	12.5	2.08	212
8420	7	1314	"	1337	900	10.3	1.14	218
8421	8	1611	"	1751	1200	8.87	.739	229
8422	9	1877	"	2221	1500	7.73	.515	234
8423	10	2116	"	2817	1900	6.90	.363	235
8424	11	2348	"	3407	2300	6.23	.271	237
8425	12	2579	"	4052	2700	5.64	.209	239
8426	13	2832	"	4937	3300	5.18	.157	239

Length of Pole, 40 Feet

Sections: 21 feet, 10 feet, 7 feet, and 6 feet 6 inches

Number	Size of butt	Weight	Thickness	Maximum load *P*	Load for deflection *D* *L*	Deflection for load *L* *D*	Factor *R*	Factor *m*
8427	5	505	*ffff*	377	250	16.2	6.47	202
8428	6	670	"	588	400	13.3	3.33	210
8429	7	856	"	844	550	10.6	1.93	221
8430	8	1064	"	1164	800	9.68	1.21	228
8431	9	1286	"	1548	1000	8.05	.805	233
8432	10	1542	"	2070	1400	7.53	.538	234
8433	11	1786	"	2557	1700	6.63	.390	239
8434	12	2001	"	3034	2000	5.98	.299	243
8435	13	2225	"	3687	2500	5.63	.225	244
8436	5	629	*Efff*	413	280	14.9	5.33	188
8437	6	871	"	701	450	11.7	2.60	193
8438	7	1160	"	1092	750	10.7	1.43	201
8439	8	1374	"	1569	1000	9.23	.923	211
8440	9	1597	"	2153	1400	8.83	.631	218
8441	10	1841	"	2730	1800	7.88	.438	222
8442	11	2090	"	3302	2200	7.06	.321	228
8443	12	2333	"	3927	2600	6.37	.245	233
8444	13	2593	"	4785	3200	5.89	.184	233
8445	5	671	*EEff*	431	280	13.9	4.96	190
8446	6	930	"	803	550	13.3	2.42	195
8447	7	1256	"	1296	850	11.2	1.32	205
8448	8	1519	"	1697	1100	9.28	.844	217
8449	9	1745	"	2153	1400	8.18	.584	224
8450	10	1989	"	2730	1800	7.38	.410	228
8451	11	2232	"	3302	2200	6.71	305	233
8452	12	2478	"	3927	2600	6.08	.234	237
8453	13	2751	"	4785	3200	5.60	.175	237
8454	5	690	*EEEf*	509	350	16.9	4.84	196
8455	6	960	"	846	550	13.0	2.37	202
8456	7	1298	"	1296	850	11.0	1.29	212
8457	8	1587	"	1697	1100	9.09	.826	225
8458	9	1846	"	2153	1400	8.02	.573	233
8459	10	2092	"	2730	1800	7.25	.403	235
8460	11	2336	"	3302	2200	6.60	.300	239
8461	12	2578	"	3927	2600	6.01	.231	242
8462	13	2852	"	4785	3200	5.57	.174	242
8463	5	702	*EEEE*	509	350	16.9	4.83	200
8464	6	978	"	846	550	13.0	2.36	206
8465	7	1325	"	1296	850	11.0	1.29	216
8466	8	1625	"	1697	1100	9.08	.825	228
8467	9	1909	"	2153	1400	8.01	.572	236
8468	10	2187	"	2730	1800	7.25	.403	239
8469	11	2432	"	3302	2200	6.60	.300	241
8470	12	2674	"	3927	2600	6.01	.231	244
8471	13	2944	"	4785	3200	5.57	.174	243

LAP-WELDED AND SEAMLESS TUBES UPSET AND EXPANDED

Uses for Upset Tubes. Upset tubes are largely used for stay tubes in marine-boiler work, but frequently tubes are upset for mechanical purposes, and in such cases they come under the heading of "Tube Specialties." As the variations of upsets in the tube specialty line are so numerous, they cannot be standardized the same as tubes upset for boiler work.

Upsetting. The upsetting of tubes consists in increasing the thickness of the wall of a tube at the ends, which increases its durability and strength. This increased thickness can be placed either on the inside or on the outside, or on both the inside and outside of the tube.

Method of Operation. The end of the tube is heated to a sufficient heat and while hot is placed in a die, and, by means of a punch with a shoulder on it, the end of the tube is stoved up, upset, or reinforced in the thickness of the wall.

When heavy reinforcements or upsets are necessary, it may take from three to four heats and operations to accomplish this, but light upsets may be obtained in one heat and one operation. Often upsets are asked for that are either very difficult or practically impossible to make, and as a guide for ordering such tubes a set of tables has been prepared showing the practical limits.

Standard Upsets. Table, pages 160–161, gives the advisable external upset for the various diameters and thicknesses of tubes. By advisable is meant the standard upset of a tube with a given diameter and thickness (see Fig. 49).

Table, pages 160–161, gives the advisable internal upset for various diameters and thicknesses of tubes. The rules covering the standard external upset of tubes also apply to standard internal upsets, as per Fig. 50.

Special Upsets. Any upsets less than that given in the table are treated as standard upsets, and any upsets greater than those given in the table are considered special upsets, as it requires more work and operations to produce them than the standard advisable upsets.

Tubes Upset and Expanded. Page 159 shows illustrations of the different kinds of upsets.

Fig. 49 shows a tube end upset on the outside, leaving the inside of the tube straight.

Fig. 50 shows a tube end upset on the inside, leaving the outside of the tube straight.

Fig. 51 shows a tube end expanded without any upset either on the inside or outside.

Fig. 52 shows a tube end upset on the outside and then expanded.

Fig. 53 shows a tube with an internal and external upset.

Upset and Expanded Tubes

Fig. 49. External Upset

Fig. 50. Internal Upset

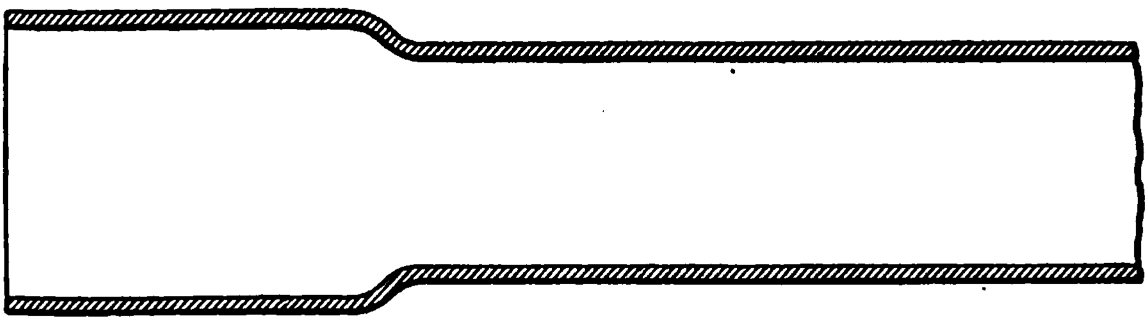


Fig. 51. Expanded Without Any Upset

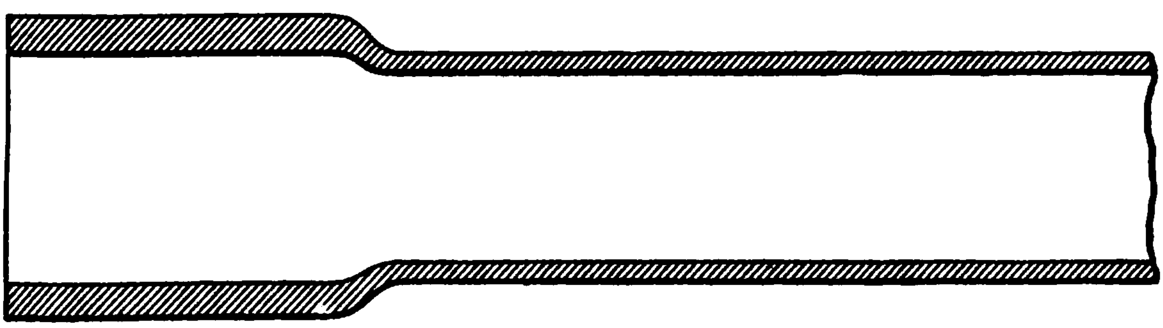


Fig. 52. External Upset and Expanded

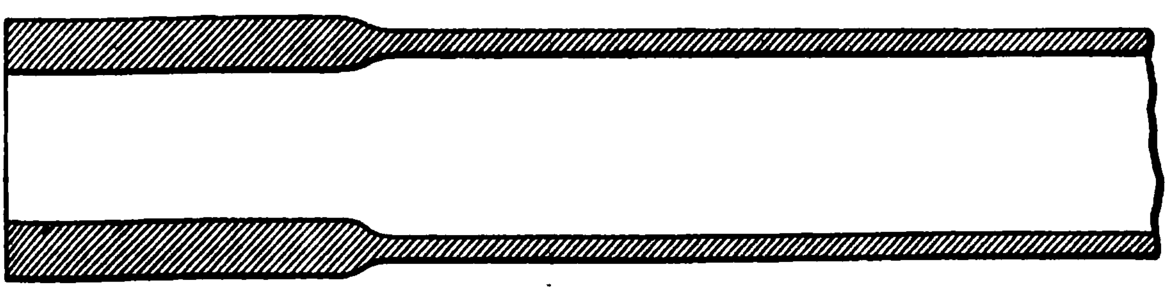


Fig. 53. Internal and External Upset

Advisable Internal Upsets for Lap-weld or Seamless Tubes

Thickness		External diameter of tubes							
Inch	Nearest B.W.G.	1½	1¾	2	2¼	2½	2¾	3	3¼
		Internal diameter of upset							
.134	10	1.03	1.28	1.53	1.78	2.03	2.28	2.53	2.78
.148	9	.98	1.23	1.48	1.73	1.98	2.23	2.48	2.73
.165	8	.92	1.17	1.42	1.67	1.92	2.17	2.42	2.67
.188	7	.84	1.09	1.34	1.59	1.84	2.09	2.34	2.59
.203	6	.79	1.04	1.29	1.54	1.79	2.04	2.29	2.54
.219	5	......	.98	1.23	1.48	1.73	1.98	2.23	2.48
.238	4	......	.91	1.16	1.41	1.66	1.91	2.16	2.41
.250	....	......	.87	1.12	1.37	1.62	1.87	2.12	2.37
.281	....	......	......	1.02	1.27	1.52	1.77	2.02	2.27
.313	....	......	......	......	1.15	1.40	1.65	1.90	2.15
.344	....	......	......	......	......	1.29	1.54	1.79	2.04
.375	....	......	......	......	......	......	1.44	1.69	1.94
.406	....	......	......	......	......	......	......	1.58	1.83
.438	....	......	......	......	......	......	......	1.46	1.71

Advisable External Upsets for Lap-weld or Seamless Tubes

Thickness		External diameter of tubes							
Inch	Nearest B.W.G.	1½	1¾	2	2¼	2½	2¾	3	3¼
		External diameter of upset							
.134	10	1.70	1.95	2.20	2.45	2.70	2.95	3.20	3.45
.148	9	1.72	1.97	2.22	2.47	2.72	2.97	3.22	3.47
.165	8	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50
.188	7	1.78	2.03	2.28	2.53	2.78	3.03	3.28	3.53
.203	6	1.80	2.05	2.30	2.55	2.80	3.05	3.30	3.55
.219	5	1.83	2.08	2.33	2.58	2.83	3.08	3.33	3.58
.238	4	1.86	2.11	2.36	2.61	2.86	3.11	3.36	3.61
.250	....	1.88	2.13	2.38	2.63	2.88	3.13	3.38	3.63
.281	....	1.92	2.17	2.42	2.67	2.92	3.17	3.42	3.67
.313	....	1.97	2.22	2.47	2.72	2.97	3.22	3.47	3.72
.344	....	2.02	2.27	2.52	2.77	3.02	3.27	3.52	3.77
.375	....	2.06	2.31	2.56	2.81	3.06	3.31	3.56	3.81
.406	....	2.11	2.36	2.61	2.86	3.11	3.36	3.61	3.86
.438	....	2.16	2.41	2.66	2.91	3.16	3.41	3.66	3.91

Diameters of upsets given are based on a length of upset 2½ inches long. Upset on tubes heavier than specified and longer than 2½ inches can be made, but will require special attention. All dimensions are nominal. All dimensions given in inches. For illustrations of tubes see Figs. 49 and 50, page 159.

Advisable Internal Upsets for Lap-weld or Seamless Tubes (Concluded)

Thickness		External diameter of tubes						
Inch	Nearest B.W.G.	3½	3¾	4	4¼	4½	4¾	5
		Internal diameter of upset						
.134	10	3.03						
.148	9	2.98	3.23	3.48	3.73	3.98	4.23	
.165	8	2.92	3.17	3.42	3.67	3.92	4.17	4.42
.188	7	2.84	3.09	3.34	3.59	3.84	4.09	4.34
.203	6	2.79	3.04	3.29	3.54	3.79	4.04	4.29
.219	5	2.73	2.98	3.23	3.48	3 73	3.98	4.23
.238	4	2.66	2.91	3.16	3.41	3.66	3.91	4.16
.250	....	2.62	2.87	3.12	3.37	3.62	3.87	4.12
.281	....	2.52	2.77	3.02	3.27	3.52	3.77	4.02
.313	....	2.40	2.65	2.90	3.15	3.40	3.65	3.90
.344	....	2.29	2.54	2.79	3.04	3.29	3.54	
.375	....	2.19	2.44	2.69	2.94	3.19		
.406	....	2.08	2.33	2.58	2.83			
.438	....	1.96	2.21	2.46				

Advisable External Upsets for Lap-weld or Seamless Tubes (Concluded)

Thickness		External diameter of tubes						
Inch	Nearest B.W.G.	3½	3¾	4	4¼	4½	4¾	5
		External diameter of upset						
.134	10	3.70						
.148	9	3.72	3.97	4.22	4.47	4.72	4.97	
.165	8	3.75	4.00	4.25	4.50	4.75	5.00	5.25
.188	7	3.78	4.03	4.28	4.53	4.78	5.03	5.28
.203	6	3.80	4.05	4.30	4.55	4.80	5.05	5.30
.219	5	3.83	4.08	4.33	4.58	4.83	5.08	5.33
.238	4	3.86	4.11	4.36	4.61	4.86	5.11	5.36
.250	....	3.88	4.13	4.38	4.63	4.88	5.13	5.38
.281	....	3.92	4.17	4.42	4.67	4.92	5.17	5.42
.313	....	3.97	4.22	4.47	4.72	4.97	5.22	5.47
.344	....	4.02	4.27	4.52	4.77	5.02	5.27	
.375	....	4.06	4.31	4.56	4.81	5.06		
.406	....	4.11	4.36	4.61	4.86			
.438	....	4.16	4.41	4.66				

Diameters of upsets given are based on a length of upset 2½ inches long. Upset on tubes heavier than specified and longer than 2½ inches can be made, but will require special attention. All dimensions are nominal. All dimensions given in inches. For illustrations of tubes see Figs. 49 and 50, page 159.

WROUGHT PIPE BENDS

The attached table gives the advisable radius and the least radius to which pipe of standard thickness may be bent.

The radii given are as short as should be used to secure good results and if they be reduced, the thickness of the pipe must be increased. As the radius is decreased, however, it becomes more difficult to avoid buckles.

For making bends, we suggest pipe as follows:—

Bends 12 inch and smaller to regular dimensions to be made of full-weight pipe.

Bends 14, 15 and 16 inch outside diameter to be not less than 3/8 inch thick.

Bends 18 inch outside diameter and larger to be not less than 7/16 inch to 1/2 inch thick.

For offset bends try to make a straight length between the bends in preference to the direct reverse bend. This is of advantage to the pipe bender.

With the welded flanges there must be a short straight length of pipe between the bend and the flange. On sizes under 4 inches this should equal, at least, one and a half diameters. On sizes over 4 inches it should equal, at least, one diameter of the pipe. In all cases it is better if equal to two diameters of straight pipe.

Table of Radii for Wrought Pipe Bends

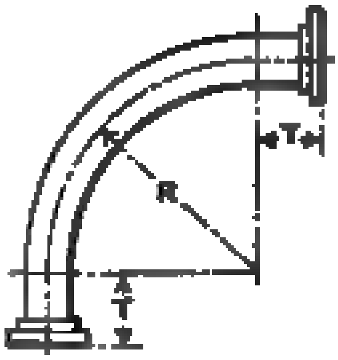
Pipe size Inches	Advisable radius — *R* Inches	Minimum radius — *R* Inches
2½	15	10
3	18	12
3½	21	14
4	24	16
4½	27	18
5	30	20
6	36	24
7	42	28
8	48	32
9	54	36
10	60	40
11	66	44
12	72	48
13	84	60
14	90	68
15	100	76
18 O.D.	125	90
20 O.D.	150	120
22 O.D.	165	132
24 O.D.	180	144

Bent Tubes.

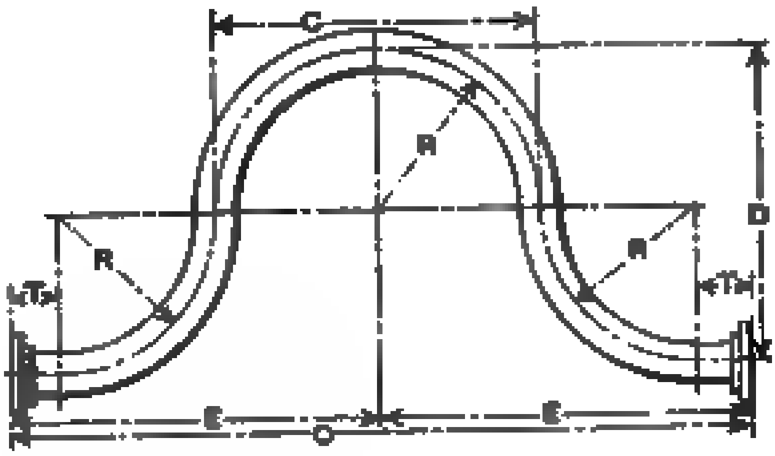
These are more difficult to bend than standard weight pipe. Try not to vary from the advisable radius given in the table. With tubes it is frequently necessary to increase the thickness over that of standard boiler tubes in order to bend them.

For illustration of Pipe Bends see page 163.

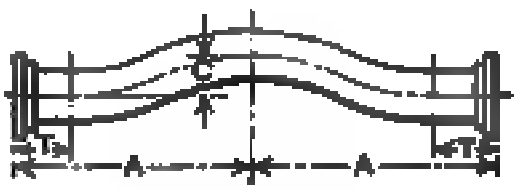
Wrought Pipe Bends



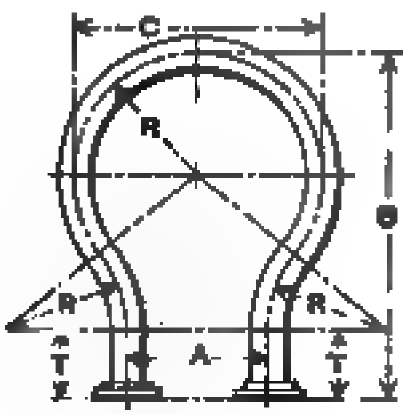
90° Bend



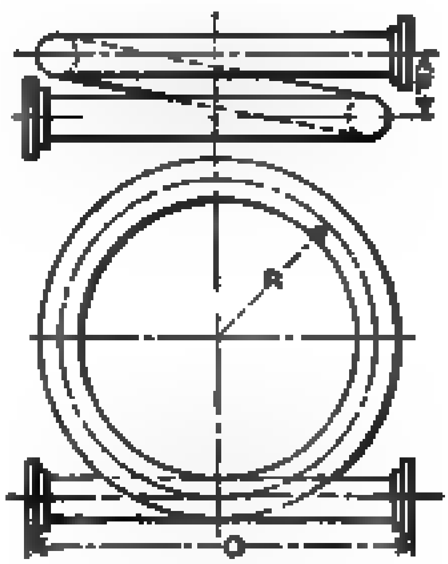
Expansion U Bend



Cross Over

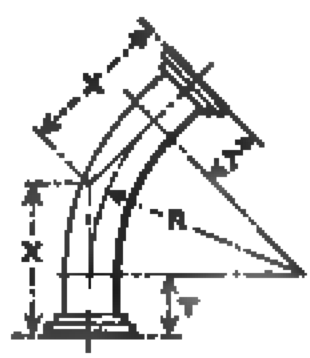


Double Offset U Bend

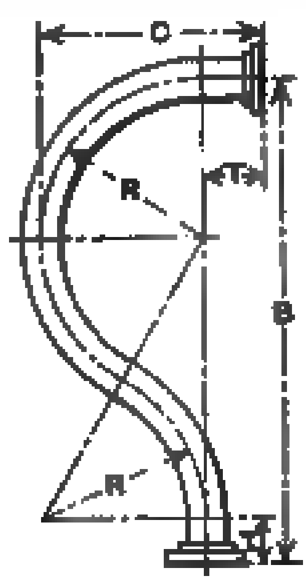


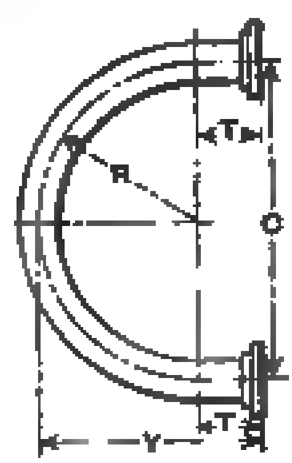
Expansion Loop

Offset



45° Bend





Single Offset U Bend

Single Offset 90° Bend

U Bend

Length of Pole, 37 Feet

Sections: 19 feet, 10 feet 6 inches, and 10 feet 6 inches

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
8307	4	346	*fff*	235	160	16.8	10.5	191
8308	5	470	"	415	280	13.6	4.84	191
8309	6	628	"	648	450	11.2	2.49	200
8310	7	799	"	930	600	8.70	1.45	207
8311	8	990	"	1282	850	7.73	.909	212
8312	9	1191	"	1705	1100	6.64	.604	215
8313	10	1426	"	2281	1500	6.06	.404	216
8314	11	1648	"	2817	1900	5.55	.292	219
8315	12	1846	"	3343	2200	4.93	.224	223
8316	13	2037	"	4062	2700	4.56	.169	222
8317	4	425	*Eff*	235	160	14.1	8.82	180
8318	5	582	"	438	300	12.0	4.00	179
8319	6	810	"	743	500	9.80	1.96	185
8320	7	1075	"	1158	750	8.10	1.08	190
8321	8	1271	"	1664	1100	7.68	.698	197
8322	9	1472	"	2292	1500	7.14	.476	202
8323	10	1696	"	3008	2000	6.62	.331	205
8324	11	1923	"	3637	2400	5.81	.242	209
8325	12	2147	"	4326	2900	5.34	.184	213
8326	13	2370	"	5272	3500	4.87	.139	213
8327	4	454	*EEf*	305	200	16.2	8.11	183
8328	5	627	"	517	350	12.9	3.68	182
8329	6	872	"	932	600	10.8	1.80	189
8330	7	1176	"	1428	950	9.30	.979	195
8331	8	1423	"	1870	1200	7.54	.628	204
8332	9	1628	"	2372	1600	6.98	.436	209
8333	10	1851	"	3008	2000	6.12	.306	211
8334	11	2072	"	3637	2400	5.47	.228	215
8335	12	2299	"	4326	2900	5.08	.175	218
8336	13	2535	"	5272	3500	4.59	.131	218
8337	4	474	*EEE*	305	200	16.0	7.98	189
8338	5	655	"	560	350	12.6	3.61	190
8339	6	916	"	932	600	10.6	1.76	197
8340	7	1238	"	1428	950	9.15	.963	203
8341	8	1524	"	1870	1200	7.40	.617	213
8342	9	1780	"	2372	1600	6.86	.429	218
8343	10	2006	"	3008	2000	6.04	.302	219
8344	11	2228	"	3637	2400	5.40	.225	221
8345	12	2448	"	4326	2900	5.02	.173	223
8346	13	2688	"	5272	3500	4.55	.130	223

Length of Pole, 38 Feet

Sections: 20 feet, 10 feet 6 inches, and 10 feet 6 inches

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
8347	4	356	*fff*	235	160	18.2	11.4	198
8348	5	485	"	402	280	14.7	5.25	198
8349	6	647	"	626	400	10.8	2.71	207
8350	7	823	"	900	600	9.48	1.58	215
8351	8	1018	"	1240	850	8.46	.995	220
8352	9	1225	"	1649	1100	7.28	.662	223
8353	10	1466	"	2206	1500	6.65	.443	224
8354	11	1693	"	2725	1800	5.78	.321	227
8355	12	1896	"	3233	2200	5.41	.246	231
8356	13	2092	"	3929	2600	4.84	.186	230
8357	4	440	*Eff*	235	160	15.2	9.47	186
8358	5	603	"	438	300	12.9	4.31	186
8359	6	839	"	743	500	10.6	2.11	192
8360	7	1113	"	1158	750	8.78	1.17	197
8361	8	1314	"	1664	1100	8.33	.757	204
8362	9	1521	"	2292	1500	7.77	.518	210
8363	10	1750	"	2909	1900	6.84	.360	212
8364	11	1983	"	3518	2300	6.07	.264	217
8365	12	2212	"	4184	2800	5.66	.202	221
8366	13	2442	"	5099	3400	5.17	.152	220
8367	4	469	*EEf*	305	200	17.5	8.76	190
8368	5	647	"	517	350	14.0	3.99	189
8369	6	901	"	902	600	11.7	1.95	196
8370	7	1214	"	1381	900	9.63	1.07	202
8371	8	1467	"	1808	1200	8.23	.686	212
8372	9	1676	"	2294	1500	7.16	.477	217
8373	10	1906	"	2909	1900	6.38	.336	219
8374	11	2132	"	3518	2300	5.75	.250	223
8375	12	2364	"	4184	2800	5.38	.192	226
8376	13	2608	"	5099	3400	4.90	.144	226
8377	4	489	*EEE*	305	200	17.3	8.63	196
8378	5	676	"	542	350	13.7	3.91	197
8379	6	945	"	902	600	11.5	1.92	204
8380	7	1276	"	1381	900	9.45	1.05	211
8381	8	1567	"	1808	1200	8.11	.676	221
8382	9	1829	"	2294	1500	7.05	.470	226
8383	10	2061	"	2909	1900	6.29	.331	227
8384	11	2288	"	3518	2300	5.68	.247	229
8385	12	2514	"	4184	2800	5.32	.190	231
8386	13	2760	"	5099	3400	4.86	.143	231

Length of Pole, 39 Feet

Sections: 21 feet, 10 feet 6 inches, and 10 feet 6 inches

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
8387	4	367	*fff*	229	150	18.5	12.3	205
8388	5	500	"	389	250	14.2	5.69	206
8389	6	666	"	607	400	11.8	2.94	215
8390	7	846	"	871	600	10.3	1.72	223
8391	8	1047	"	1201	800	8.72	1.09	228
8392	9	1259	"	1597	1100	7.95	.723	231
8393	10	1507	"	2136	1400	6.78	.484	232
8394	11	1739	"	2638	1800	6.34	.352	235
8395	12	1946	"	3130	2100	5.67	.270	239
8396	13	2146	"	3804	2500	5.08	.203	238
8397	4	455	*Eff*	235	160	16.3	10.2	193
8398	5	623	"	438	300	13.9	4.63	192
8399	6	867	"	743	500	11.4	2.28	199
8400	7	1151	"	1158	750	9.45	1.26	204
8401	8	1358	"	1664	1100	9.02	.820	212
8402	9	1570	"	2221	1500	8.43	.562	217
8403	10	1805	"	2817	1900	7.45	.392	220
8404	11	2043	"	3406	2300	6.60	.287	225
8405	12	2278	"	4052	2700	5.94	.220	229
8406	13	2514	"	4937	3300	5.48	.166	228
8407	4	484	*EEf*	305	200	18.9	9.45	197
8408	5	668	"	517	350	15.1	4.31	196
8409	6	929	"	873	600	12.7	2.12	203
8410	7	1252	"	1337	900	10.4	1.16	211
8411	8	1510	"	1751	1200	8.99	.749	220
8412	9	1725	"	2221	1500	7.83	.522	225
8413	10	1960	"	2817	1900	6.97	.367	227
8414	11	2192	"	3406	2300	6.28	.273	231
8415	12	2430	"	4052	2700	5.67	.210	234
8416	13	2680	"	4937	3300	5.21	.158	234
8417	4	504	*EEE*	305	200	18.6	9.32	203
8418	5	696	"	525	350	14.8	4.24	204
8419	6	973	"	873	600	12.5	2.08	212
8420	7	1314	"	1337	900	10.3	1.14	218
8421	8	1611	"	1751	1200	8.87	.739	229
8422	9	1877	"	2221	1500	7.73	.515	234
8423	10	2116	"	2817	1900	6.90	.363	235
8424	11	2348	"	3407	2300	6.23	.271	237
8425	12	2579	"	4052	2700	5.64	.209	239
8426	13	2832	"	4937	3300	5.18	.157	239

Length of Pole, 40 Feet

Sections: 21 feet, 10 feet, 7 feet, and 6 feet 6 inches

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
8427	5	505	*ffff*	377	250	16.2	6.47	202
8428	6	670	"	588	400	13.3	3.33	210
8429	7	856	"	844	550	10.6	1.93	221
8430	8	1064	"	1164	800	9.68	1.21	228
8431	9	1286	"	1548	1000	8.05	.805	233
8432	10	1542	"	2070	1400	7.53	.538	234
8433	11	1786	"	2557	1700	6.63	.390	239
8434	12	2001	"	3034	2000	5.98	.299	243
8435	13	2225	"	3687	2500	5.63	.225	244
8436	5	629	*Efff*	413	280	14.9	5.33	188
8437	6	871	"	701	450	11.7	2.60	193
8438	7	1160	"	1092	750	10.7	1.43	201
8439	8	1374	"	1569	1000	9.23	.923	211
8440	9	1597	"	2153	1400	8.83	.631	218
8441	10	1841	"	2730	1800	7.88	.438	222
8442	11	2090	"	3302	2200	7.06	.321	228
8443	12	2333	"	3927	2600	6.37	.245	233
8444	13	2593	"	4785	3200	5.89	.184	233
8445	5	671	*EEff*	431	280	13.9	4.96	190
8446	6	930	"	803	550	13.3	2.42	195
8447	7	1256	"	1296	850	11.2	1.32	205
8448	8	1519	"	1697	1100	9.28	.844	217
8449	9	1745	"	2153	1400	8.18	.584	224
8450	10	1989	"	2730	1800	7.38	.410	228
8451	11	2232	"	3302	2200	6.71	305	233
8452	12	2478	"	3927	2600	6.08	.234	237
8453	13	2751	"	4785	3200	5.60	.175	237
8454	5	690	*EEEf*	509	350	16.9	4.84	196
8455	6	960	"	846	550	13.0	2.37	202
8456	7	1298	"	1296	850	11.0	1.29	212
8457	8	1587	"	1697	1100	9.09	.826	225
8458	9	1846	"	2153	1400	8.02	.573	233
8459	10	2092	"	2730	1800	7.25	.403	235
8460	11	2336	"	3302	2200	6.60	.300	239
8461	12	2578	"	3927	2600	6.01	.231	242
8462	13	2852	"	4785	3200	5.57	.174	242
8463	5	702	*EEEE*	509	350	16.9	4.83	200
8464	6	978	"	846	550	13.0	2.36	206
8465	7	1325	"	1296	850	11.0	1.29	216
8466	8	1625	"	1697	1100	9.08	.825	228
8467	9	1909	"	2153	1400	8.01	.572	236
8468	10	2187	"	2730	1800	7.25	.403	239
8469	11	2432	"	3302	2200	6.60	.300	241
8470	12	2674	"	3927	2600	6.01	.231	244
8471	13	2944	"	4785	3200	5.57	.174	243

Length of Pole, 35 Feet

Sections: 21 feet, 10 feet, and 7 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
8137	4	343	*fff*	263	180	13.6	7.54	187
8138	5	468	"	446	300	10.5	3.51	190
8139	6	621	"	695	450	8.33	1.85	196
8140	7	786	"	998	650	7.15	1.10	201
8141	8	969	"	1375	900	6.28	.698	204
8142	9	1162	"	1829	1200	5.60	.467	206
8143	10	1390	"	2447	1600	5.00	.313	206
8144	11	1600	"	3022	2000	4.58	.229	210
8145	12	1781	"	3586	2400	4.25	.177	213
8146	13	1962	"	4358	2900	3.86	.133	211
8147	4	431	*Eff*	310	200	12.1	6.06	176
8148	5	592	"	578	400	11.1	2.77	178
8149	6	822	"	981	650	8.97	1.38	182
8150	7	1090	"	1529	1000	7.73	.773	186
8151	8	1279	"	2006	1300	6.63	.510	191
8152	9	1473	"	2544	1700	6.00	.353	195
8153	10	1688	"	3227	2200	5.43	.247	197
8154	11	1904	"	3902	2600	4.76	.183	201
8155	12	2113	"	4641	3100	4.37	.141	204
8156	13	2329	"	5656	3800	4.03	.106	203
8157	4	459	*EEf*	349	220	12.6	5.73	183
8158	5	634	"	601	400	10.5	2.62	185
8159	6	881	"	1000	650	8.52	1.31	190
8160	7	1186	"	1532	1000	7.26	.726	195
8161	8	1424	"	2006	1300	6.20	.477	202
8162	9	1621	"	2544	1700	5.70	.335	204
8163	10	1836	"	3227	2200	5.19	.236	205
8164	11	2046	"	3902	2600	4.60	.177	208
8165	12	2258	"	4641	3100	4.25	.137	211
8166	13	2487	"	5656	3800	3.91	.103	209
8167	4	472	*EEE*	349	220	12.6	5.71	186
8168	5	653	"	601	400	10.4	2.61	189
8169	6	911	"	1000	650	8.45	1.30	194
8170	7	1228	"	1532	1000	7.23	.723	198
8171	8	1492	"	2006	1300	6.18	.475	205
8172	9	1723	"	2544	1700	5.66	.333	208
8173	10	1940	"	3227	2200	5.17	.235	209
8174	11	2150	"	3902	2600	4.60	.177	211
8175	12	2357	"	4641	3100	4.22	.136	212
8176	13	2589	"	5656	3800	3.88	.102	211

Length of Pole, 35 Feet

Sections: 18 feet 6 inches, 9 feet 6 inches, 6 feet 6 inches, and 5 feet

Number	Size of butt	Weight	Thick-ness	Maxi-mum load P	Load for deflec-tion D L	Deflec-tion for load L D	Factor R	Factor m
8177	5	451	*ffff*	446	300	11.6	3.88	175
8178	6	598	"	695	450	9.00	2.00	183
8179	7	764	"	998	650	7.54	1.16	191
8180	8	949	"	1375	900	6.60	.733	196
8181	9	1147	"	1829	1200	5.84	.487	199
8182	10	1375	"	2447	1600	5.22	.326	200
8183	11	1592	"	3022	2000	4.72	.236	204
8184	12	1784	"	3586	2400	4.34	.181	208
8185	13	1980	"	4358	2900	3.94	.136	207
8186	5	560	*Efff*	482	300	9.60	3.20	164
8187	6	776	"	817	550	8.64	1.57	168
8188	7	1032	"	1274	850	7.34	.864	174
8189	8	1223	"	1830	1200	6.71	.559	182
8190	9	1421	"	2522	1700	6.49	.382	187
8191	10	1638	"	3227	2200	5.83	.265	190
8192	11	1860	"	3902	2600	5.04	.194	195
8193	12	2076	"	4641	3100	4.59	.148	198
8194	13	2304	"	5656	3900	4.37	.112	198
8195	5	600	*EEff*	554	350	10.4	2.96	166
8196	6	832	"	1000	650	9.43	1.45	172
8197	7	1124	"	1532	1000	7.89	.789	179
8198	8	1360	"	2006	1300	6.58	.506	188
8199	9	1561	"	2544	1700	5.98	.352	193
8200	10	1778	"	3227	2200	5.43	.247	195
8201	11	1995	"	3902	2600	4.78	.184	200
8202	12	2214	"	4641	3100	4.37	.141	203
8203	13	2454	"	5656	3900	4.13	.106	203
8204	5	618	*EEEf*	601	400	11.6	2.90	172
8205	6	859	"	1000	650	9.23	1.42	178
8206	7	1162	"	1532	1000	7.75	.775	185
8207	8	1423	"	2006	1300	6.47	.498	195
8208	9	1655	"	2544	1700	5.88	.346	201
8209	10	1874	"	3227	2200	5.37	.244	202
8210	11	2091	"	3902	2600	4.73	.182	205
8211	12	2306	"	4641	3100	4.34	.140	207
8212	13	2548	"	5656	3900	4.10	.105	206
8213	5	627	*EEEE*	601	400	11.6	2.90	174
8214	6	873	"	1000	650	9.23	1.42	180
8215	7	1183	"	1532	1000	7.75	.775	187
8216	8	1452	"	2006	1300	6.46	.497	196
8217	9	1703	"	2544	1700	5.88	.346	202
8218	10	1947	"	3227	2200	5.37	.244	203
8219	11	2165	"	3902	2600	4.73	.182	206
8220	12	2380	"	4641	3100	4.34	.140	207
8221	13	2619	"	5656	3900	4.10	.105	207

Length of Pole, 36 Feet

Sections: 18 feet 6 inches, 10 feet 6 inches, and 10 feet

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
8222	4	337	*fff*	242	160	15.1	9.45	185
8223	5	459	"	430	280	12.2	4.35	185
8224	6	613	"	670	450	10.1	2.24	193
8225	7	780	"	963	650	8.45	1.30	201
8226	8	966	"	1327	900	7.38	.820	205
8227	9	1162	"	1765	1200	6.53	.544	208
8228	10	1391	"	2361	1600	5.82	.364	209
8229	11	1608	"	2916	1900	5.00	.263	212
8230	12	1801	"	3460	2300	4.65	.202	216
8231	13	1987	"	4205	2800	4.26	.152	215
8232	4	415	*Eff*	242	160	12.7	7.95	174
8233	5	568	"	452	300	10.8	3.60	174
8234	6	790	"	766	500	8.85	1.77	179
8235	7	1049	"	1195	800	7.79	.974	184
8236	8	1240	"	1716	1100	6.92	.629	191
8237	9	1436	"	2364	1600	6.88	.430	196
8238	10	1654	"	3113	2100	6.26	.298	198
8239	11	1876	"	3765	2500	5.45	.218	203
8240	12	2094	"	4478	3000	4.98	.166	206
8241	13	2311	"	5457	3600	4.50	.125	205
8242	4	444	*EEf*	314	200	14.6	7.29	177
8243	5	613	"	554	350	11.6	3.31	177
8244	6	852	"	965	650	10.5	1.62	183
8245	7	1149	"	1478	1000	8.81	.881	190
8246	8	1392	"	1935	1300	7.33	.564	198
8247	9	1592	"	2455	1600	6.27	.392	202
8248	10	1809	"	3113	2100	5.80	.276	205
8249	11	2025	"	3765	2500	5.13	.205	208
8250	12	2246	"	4478	3000	4.71	.157	212
8251	13	2477	"	5457	3600	4.25	.118	210
8252	4	462	*EEE*	314	200	14.4	7.19	183
8253	5	640	"	580	400	13.0	3.25	184
8254	6	894	"	965	650	10.3	1.59	191
8255	7	1208	"	1478	1000	8.67	.867	197
8256	8	1488	"	1935	1300	7.23	.556	206
8257	9	1737	"	2455	1600	6.18	.386	211
8258	10	1957	"	3113	2100	5.73	.273	212
8259	11	2173	"	3765	2500	5.08	.203	214
8260	12	2388	"	4478	3000	4.68	.156	216
8261	13	2622	"	5457	3600	4.25	.118	214

Length of Pole, 36 Feet

Sections: 19 feet, 9 feet 6 inches, 7 feet, and 5 feet

Number	Size of butt	Weight	Thick-ness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
8262	5	462	*ffff*	430	280	12.1	4.33	181
8263	6	613	"	670	450	10.0	2.23	189
8264	7	783	"	963	650	8.45	1.30	197
8265	8	973	"	1327	900	7.34	.816	203
8266	9	1175	"	1765	1200	6.50	.542	206
8267	10	1409	"	2361	1600	5.81	.363	207
8268	11	1631	"	2916	1900	5.00	.263	211
8269	12	1829	"	3460	2300	4.65	.202	215
8270	13	2030	"	4205	2800	4.26	.152	214
8271	5	574	*Efff*	466	300	10.7	3.57	169
8272	6	796	"	791	550	9.63	1.75	174
8273	7	1059	"	1233	800	7.70	.963	180
8274	8	1254	"	1771	1200	7.46	.622	188
8275	9	1457	"	2440	1600	6.80	.425	194
8276	10	1679	"	3113	2100	6.20	.295	197
8277	11	1907	"	3765	2500	5.40	.216	201
8278	12	2129	"	4478	3000	4.95	.165	206
8279	13	2363	"	5457	3600	4.46	.124	204
8280	5	614	*EEff*	517	350	11.6	3.31	171
8281	6	852	"	964	650	10.5	1.62	177
8282	7	1150	"	1478	1000	8.80	.880	185
8283	8	1392	"	1935	1300	7.35	.565	194
8284	9	1597	"	2455	1600	6.27	.392	199
8285	10	1820	"	3113	2100	5.80	.276	202
8286	11	2042	"	3765	2500	5.13	.205	206
8287	12	2267	"	4478	3000	4.71	.157	210
8288	13	2513	"	5457	3600	4.25	.118	209
8289	5	633	*EEEf*	580	400	13.0	3.24	178
8290	6	881	"	965	650	10.3	1.58	184
8291	7	1191	"	1478	1000	8.64	.864	192
8292	8	1459	"	1935	1300	7.22	.555	202
8293	9	1699	"	2455	1600	6.16	.385	208
8294	10	1923	"	3113	2100	5 69	.271	209
8295	11	2146	"	3765	2500	5.05	.202	212
8296	12	2366	"	4478	3000	4.68	.156	214
8297	13	2614	"	5457	3600	4.21	.117	213
8298	5	642	*EEEE*	580	400	12.9	3.23	180
8299	6	895	"	965	650	10.3	1.58	186
8300	7	1212	"	1478	1000	8.64	.864	193
8301	8	1488	"	1935	1300	7.20	.554	203
8302	9	1747	"	2455	1600	6.16	.385	209
8303	10	1996	"	3113	2100	5.69	.271	210
8304	11	2220	"	3765	2500	5.05	.202	213
8305	12	2440	"	4478	3000	4.68	.156	215
8306	13	2685	"	5457	3600	4.21	.117	214

Length of Pole, 37 Feet

Sections: 19 feet, 10 feet 6 inches, and 10 feet 6 inches

Number	Size of butt	Weight	Thick-ness	Maxi-mum load *P*	Load for deflec-tion *D* *L*	Deflec-tion for load *L* *D*	Factor *R*	Factor *m*
8307	4	346	*fff*	235	160	16.8	10.5	191
8308	5	470	"	415	280	13.6	4.84	191
8309	6	628	"	648	450	11.2	2.49	200
8310	7	799	"	930	600	8.70	1.45	207
8311	8	990	"	1282	850	7.73	.909	212
8312	9	1191	"	1705	1100	6.64	.604	215
8313	10	1426	"	2281	1500	6.06	.404	216
8314	11	1648	"	2817	1900	5.55	.292	219
8315	12	1846	"	3343	2200	4.93	.224	223
8316	13	2037	"	4062	2700	4.56	.169	222
8317	4	425	*Eff*	235	160	14.1	8.82	180
8318	5	582	"	438	300	12.0	4.00	179
8319	6	810	"	743	500	9.80	1.96	185
8320	7	1075	"	1158	750	8.10	1.08	190
8321	8	1271	"	1664	1100	7.68	.698	197
8322	9	1472	"	2292	1500	7.14	.476	202
8323	10	1696	"	3008	2000	6.62	.331	205
8324	11	1923	"	3637	2400	5.81	.242	209
8325	12	2147	"	4326	2900	5.34	.184	213
8326	13	2370	"	5272	3500	4.87	.139	213
8327	4	454	*EEf*	305	200	16.2	8.11	183
8328	5	627	"	517	350	12.9	3.68	182
8329	6	872	"	932	600	10.8	1.80	189
8330	7	1176	"	1428	950	9.30	.979	195
8331	8	1423	"	1870	1200	7.54	.628	204
8332	9	1628	"	2372	1600	6.98	.436	209
8333	10	1851	"	3008	2000	6.12	.306	211
8334	11	2072	"	3637	2400	5.47	.228	215
8335	12	2299	"	4326	2900	5.08	.175	218
8336	13	2535	"	5272	3500	4.59	.131	218
8337	4	474	*EEE*	305	200	16.0	7.98	189
8338	5	655	"	560	350	12.6	3.61	190
8339	6	916	"	932	600	10.6	1.76	197
8340	7	1238	"	1428	950	9.15	.963	203
8341	8	1524	"	1870	1200	7.40	.617	213
8342	9	1780	"	2372	1600	6.86	.429	218
8343	10	2006	"	3008	2000	6.04	.302	219
8344	11	2228	"	3637	2400	5.40	.225	221
8345	12	2448	"	4326	2900	5.02	.173	223
8346	13	2688	"	5272	3500	4.55	.130	223

Length of Pole, 38 Feet

Sections: 20 feet, 10 feet 6 inches, and 10 feet 6 inches

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
8347	4	356	*fff*	235	160	18.2	11.4	198
8348	5	485	"	402	280	14.7	5.25	198
8349	6	647	"	626	400	10.8	2.71	207
8350	7	823	"	900	600	9.48	1.58	215
8351	8	1018	"	1240	850	8.46	.995	220
8352	9	1225	"	1649	1100	7.28	.662	223
8353	10	1466	"	2206	1500	6.65	.443	224
8354	11	1693	"	2725	1800	5.78	.321	227
8355	12	1896	"	3233	2200	5.41	.246	231
8356	13	2092	"	3929	2600	4.84	.186	230
8357	4	440	*Eff*	235	160	15.2	9.47	186
8358	5	603	"	438	300	12.9	4.31	186
8359	6	839	"	743	500	10.6	2.11	192
8360	7	1113	"	1158	750	8.78	1.17	197
8361	8	1314	"	1664	1100	8.33	.757	204
8362	9	1521	"	2292	1500	7.77	.518	210
8363	10	1750	"	2909	1900	6.84	.360	212
8364	11	1983	"	3518	2300	6.07	.264	217
8365	12	2212	"	4184	2800	5.66	.202	221
8366	13	2442	"	5099	3400	5.17	.152	220
8367	4	469	*EEf*	305	200	17.5	8.76	190
8368	5	647	"	517	350	14.0	3.99	189
8369	6	901	"	902	600	11.7	1.95	196
8370	7	1214	"	1381	900	9.63	1.07	202
8371	8	1467	"	1808	1200	8.23	.686	212
8372	9	1676	"	2294	1500	7.16	.477	217
8373	10	1906	"	2909	1900	6.38	.336	219
8374	11	2132	"	3518	2300	5.75	.250	223
8375	12	2364	"	4184	2800	5.38	.192	226
8376	13	2608	"	5099	3400	4.90	.144	226
8377	4	489	*EEE*	305	200	17.3	8.63	196
8378	5	676	"	542	350	13.7	3.91	197
8379	6	945	"	902	600	11.5	1.92	204
8380	7	1276	"	1381	900	9.45	1.05	211
8381	8	1567	"	1808	1200	8.11	.676	221
8382	9	1829	"	2294	1500	7.05	.470	226
8383	10	2061	"	2909	1900	6.29	.331	227
8384	11	2288	"	3518	2300	5.68	.247	229
8385	12	2514	"	4184	2800	5.32	.190	231
8386	13	2760	"	5099	3400	4.86	.143	231

Length of Pole, 39 Feet

Sections: 21 feet, 10 feet 6 inches, and 10 feet 6 inches

Number	Size of butt	Weight	Thick-ness	Maxi-mum load P	Load for deflec-tion D L	Deflec-tion for load L D	Factor R	Factor m
8387	4	367	*fff*	229	150	18.5	12.3	205
8388	5	500	"	389	250	14.2	5.69	206
8389	6	666	"	607	400	11.8	2.94	215
8390	7	846	"	871	600	10.3	1.72	223
8391	8	1047	"	1201	800	8.72	1.09	228
8392	9	1259	"	1597	1100	7.95	.723	231
8393	10	1507	"	2136	1400	6.78	.484	232
8394	11	1739	"	2638	1800	6.34	.352	235
8395	12	1946	"	3130	2100	5.67	.270	239
8396	13	2146	"	3804	2500	5.08	.203	238
8397	4	455	*Eff*	235	160	16.3	10.2	193
8398	5	623	"	438	300	13.9	4.63	192
8399	6	867	"	743	500	11.4	2.28	199
8400	7	1151	"	1158	750	9.45	1.26	204
8401	8	1358	"	1664	1100	9.02	.820	212
8402	9	1570	"	2221	1500	8.43	.562	217
8403	10	1805	"	2817	1900	7.45	.392	220
8404	11	2043	"	3406	2300	6.60	.287	225
8405	12	2278	"	4052	2700	5.94	.220	229
8406	13	2514	"	4937	3300	5.48	.166	228
8407	4	484	*EEf*	305	200	18.9	9.45	197
8408	5	668	"	517	350	15.1	4.31	196
8409	6	929	"	873	600	12.7	2.12	203
8410	7	1252	"	1337	900	10.4	1.16	211
8411	8	1510	"	1751	1200	8.99	.749	220
8412	9	1725	"	2221	1500	7.83	.522	225
8413	10	1960	"	2817	1900	6.97	.367	227
8414	11	2192	"	3406	2300	6.28	.273	231
8415	12	2430	"	4052	2700	5.67	.210	234
8416	13	2680	"	4937	3300	5.21	.158	234
8417	4	504	*EEE*	305	200	18.6	9.32	203
8418	5	696	"	525	350	14.8	4.24	204
8419	6	973	"	873	600	12.5	2.08	212
8420	7	1314	"	1337	900	10.3	1.14	218
8421	8	1611	"	1751	1200	8.87	.739	229
8422	9	1877	"	2221	1500	7.73	.515	234
8423	10	2116	"	2817	1900	6.90	.363	235
8424	11	2348	"	3407	2300	6.23	.271	237
8425	12	2579	"	4052	2700	5.64	.209	239
8426	13	2832	"	4937	3300	5.18	.157	239

Length of Pole, 40 Feet

Sections: 21 feet, 10 feet, 7 feet, and 6 feet 6 inches

Number	Size of butt	Weight	Thickness	Maximum load P	Load for deflection D L	Deflection for load L D	Factor R	Factor m
8427	5	505	ffff	377	250	16.2	6.47	202
8428	6	670	"	588	400	13.3	3.33	210
8429	7	856	"	844	550	10.6	1.93	221
8430	8	1064	"	1164	800	9.68	1.21	228
8431	9	1286	"	1548	1000	8.05	.805	233
8432	10	1542	"	2070	1400	7.53	.538	234
8433	11	1786	"	2557	1700	6.63	.390	239
8434	12	2001	"	3034	2000	5.98	.299	243
8435	13	2225	"	3687	2500	5.63	.225	244
8436	5	629	Efff	413	280	14.9	5.33	188
8437	6	871	"	701	450	11.7	2.60	193
8438	7	1160	"	1092	750	10.7	1.43	201
8439	8	1374	"	1569	1000	9.23	.923	211
8440	9	1597	"	2153	1400	8.83	.631	218
8441	10	1841	"	2730	1800	7.88	.438	222
8442	11	2090	"	3302	2200	7.06	.321	228
8443	12	2333	"	3927	2600	6.37	.245	233
8444	13	2593	"	4785	3200	5.89	.184	233
8445	5	671	EEff	431	280	13.9	4.96	190
8446	6	930	"	803	550	13.3	2.42	195
8447	7	1256	"	1296	850	11.2	1.32	205
8448	8	1519	"	1697	1100	9.28	.844	217
8449	9	1745	"	2153	1400	8.18	.584	224
8450	10	1989	"	2730	1800	7.38	.410	228
8451	11	2232	"	3302	2200	6.71	.305	233
8452	12	2478	"	3927	2600	6.08	.234	237
8453	13	2751	"	4785	3200	5.60	.175	237
8454	5	690	EEEf	509	350	16.9	4.84	196
8455	6	960	"	846	550	13.0	2.37	202
8456	7	1298	"	1296	850	11.0	1.29	212
8457	8	1587	"	1697	1100	9.09	.826	225
8458	9	1846	"	2153	1400	8.02	.573	233
8459	10	2092	"	2730	1800	7.25	.403	235
8460	11	2336	"	3302	2200	6.60	.300	239
8461	12	2578	"	3927	2600	6.01	.231	242
8462	13	2852	"	4785	3200	5.57	.174	242
8463	5	702	EEEE	509	350	16.9	4.83	200
8464	6	978	"	846	550	13.0	2.36	206
8465	7	1325	"	1296	850	11.0	1.29	216
8466	8	1625	"	1697	1100	9.08	.825	228
8467	9	1909	"	2153	1400	8.01	.572	236
8468	10	2187	"	2730	1800	7.25	.403	239
8469	11	2432	"	3302	2200	6.60	.300	241
8470	12	2674	"	3927	2600	6.01	.231	244
8471	13	2944	"	4785	3200	5.57	.174	243

BUTTED AND STRAPPED JOINTS—SINGLE AND DOUBLE RIVETED

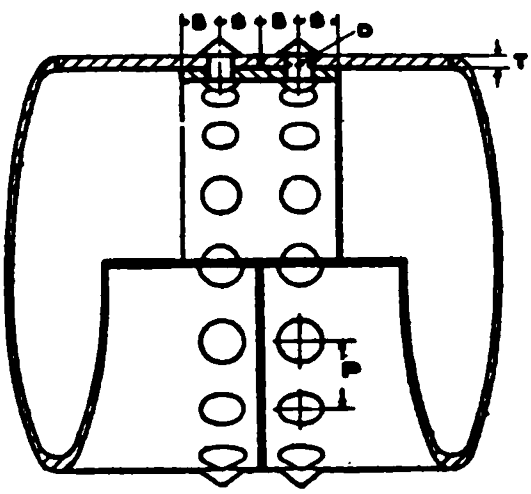


Fig. 54. Joint Flush Outside—Single Riveted

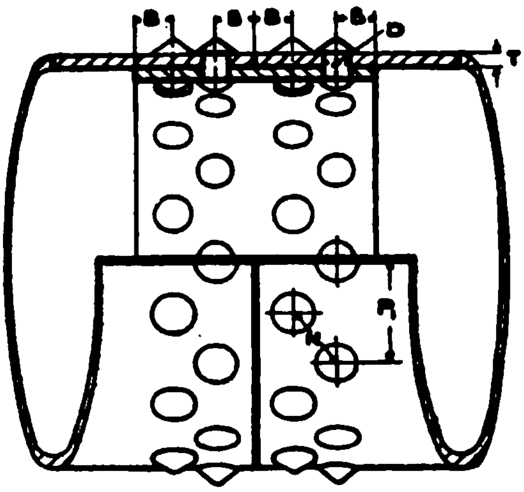


Fig. 55. Joint Flush Outside—Double Riveted

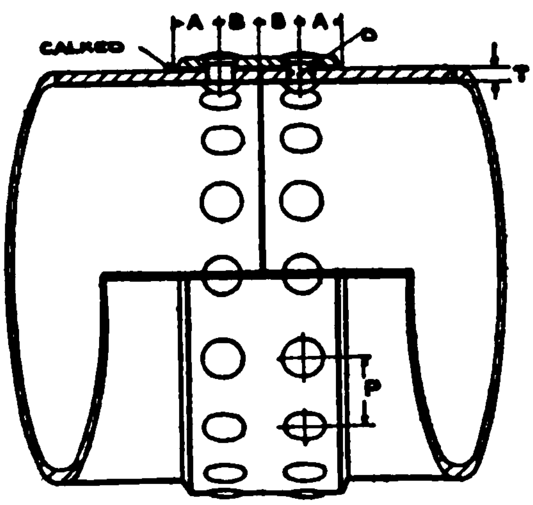


Fig. 56. Joint Flush Inside—Single Riveted

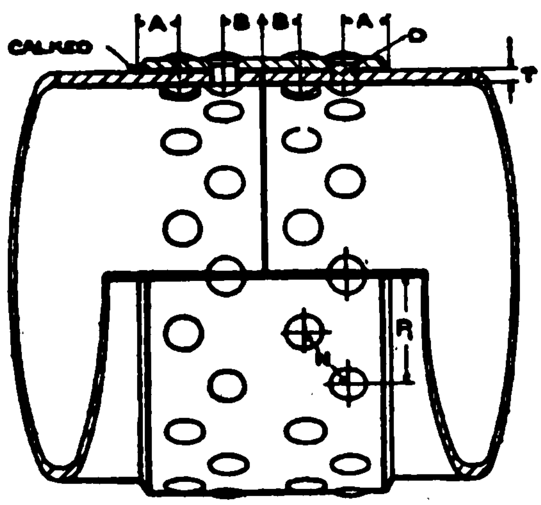


Fig. 57. Joint Flush Inside—Double Riveted

This class of goods is special, and made to suit the conditions as indicated by the customer's requirements. Since there seldom are two parallel cases, it is difficult to give any rule for these joints. They usually take on quite different forms, according to the use to which applied. In a general way it may be said they have been employed on pipe mostly to piece out boiler flues, or to piece out pipes used as piles, masts, or booms.

When used for flues, it is generally customary to put the strap on the outside and then countersink the rivets on the outside, leaving the button heads on the inside. The outside countersinking is done to avoid unnecessary enlargement of the hole in the flue sheet. The end of the flue is then expanded to fit this enlarged hole in the flue sheet. Since the flue is connected to the tube sheet by single riveting, it is seldom necessary, and always unadvisable, to double rivet because it is more difficult to calk a double rivet seam satisfactorily.

Strapped joints used for piles, etc., are usually so made that the riveting is secondary to the beam action of the strap. On piles the strap is usually made several diameters long, and attached to the end of one of the pieces by a few well-scattered rivets.

The connection between the sleeve and the second piece is made in the field by means of patch bolts. For some uses where the joint section is relied on mainly for its beam action or lateral stiffness, the sleeve is inserted into each piece for a distance of about one-half to two diameters.

The sleeve is turned slightly tapered with its largest diameter at the center, and the pipes are bored to match. After assembling, however, a few patch bolts are placed about midway between the end of pipe and the end of sleeve.

For the information of those who wish to use these joints, it may be said that for short sleeves the thickness is usually from one and one-half to twice the thickness of the pipe, and that for long sleeves, used for strength as beams, the thickness is determined by the rules for strength of beams.

The following rules may be used for figuring the riveting, spacing, etc.

Figs. 54 and 56
Single Riveted

$D = 1.5\,T + .16$ inch
$P = 2\,D + .4$ inch
$A = 1.5\,D + 1/8$ inch
$B = 1.5\,D$

Figs. 55 and 57
Double Riveted

$D = 1.5\,T + .16$ inch
$P_1 = 3\,D + .78$ inch
$N = 2\,D + .4$ inch
$A = 1.5\,D + 1/8$ inch
$B = 1.5\,D.$

BUMP JOINTS — SINGLE AND DOUBLE RIVETED

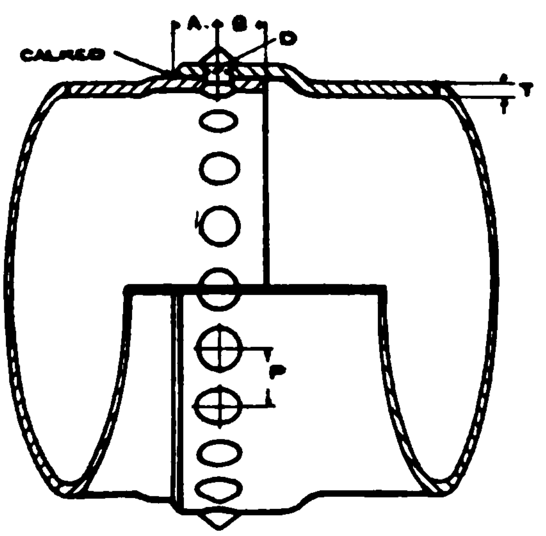


Fig. 58

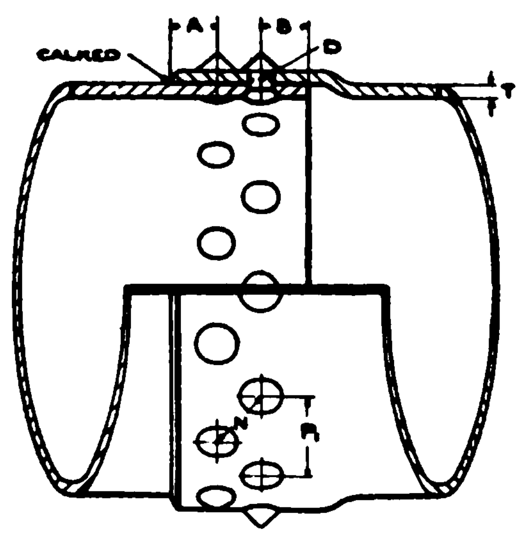


Fig. 59

This joint has been largely used in the past for coupling two pieces of boiler-flue together in order to make a flue longer than 21 feet. The necessity for this practice has ceased as it is now possible to secure flues up to 20 inches in diameter and 40 feet in length. This joint is also being used extensively for long lines of large size pipe, say 20 to 30 inches in

diameter, and for such lines it has the advantage of low cost in comparison with the high pressure it will carry, being serviceable for pressures up to 500 pounds, when used on flues or pipe of the proper thickness, and although it entails difficulty in assembling with lines buried in the ground its advantages more than offset its disadvantages. Many of the Pacific Coast Hydro Electric Developments have used this joint in this manner with satisfaction and probably at less cost than if the pipe had been connected by flanges welded to them, or other means.

This joint is not adapted to small sizes, say under 20 inches, because of the difficulty of obtaining men who can work continuously inside of a pipe less than 20 inches in diameter when riveting joints. For boiler-flues it is practical, because of its accessibility in riveting to add 10 or 15 feet to a 12-inch tube.

The double riveted joint, Fig. 59, exhibits the spigot end as straight. This form usually entails accurate sizing of the two parts for each joint so that those identical pieces will be assembled in the field.

In order to make the joints interchangeable in the erection and to facilitate assembling and calking, it is advisable to expand the spigot end on a slight taper for single riveted joints, as shown by Fig. 58. This enables laying out the rivet holes accurately to a gage before punching. The tapered spigot can, of course, be applied to the double riveted joint, Fig. 59.

Since the strain imposed by the pressure on the girth joint is one-half of the strain imposed on the longitudinal joint, it is evident that the riveted girth joint need have only one-half of the strength of the welded joint or longitudinal seam. Therefore with welded or seamless pipe it is never necessary to use double riveted joints except in those locations where the pipe above ground makes a bend, or where the pipe must act as a beam and the joint is exposed to strains produced by flexure.

The following rule can be used for figuring the riveting, spacing, etc.:

Fig. 58
Single Riveted

$D = 1.5\,T + .16$ inch
$P = 2\,D + .4$ inch
$A = 1.5\,D + 1/8$ inch
$B = 1.5\,D$

Fig. 59
Double Riveted

$D = 1.5\,T + .16$ inch
$P_1 = 3\,D + .78$ inch
$N = 2\,D + .4$ inch
$A = 1.5\,D + 1/8$ inch
$B = 1.5\,D$

VALVES AND FITTINGS

It is the intention to present information in this section regarding valves and fittings, which will be of value to all who use them.

Valves and fittings are designed to conform to the pipe connections of the line in which they are used. Wrought pipe is usually connected in one of three ways, screwed, flanged, or leaded joints.

Screwed. Pipe in sizes from ⅛ inch to 15 inches inclusive, is regularly threaded on the ends, and is connected by means of threaded couplings.

Flanged. Pipe in sizes 1¼ inches and larger is frequently connected by drilled flanges bolted together, the joint being made by a gasket between the flange faces.

Flanges are attached to the pipe in a variety of ways. The most common method for sizes of pipe from 1¼ inches to 15 inches inclusive, is by screwing them on the pipe. Many prefer peened flanges for pipe larger than 6 inches. The peened flange is shrunk on the end of the pipe, and the latter is then peened over or expanded into a recess in the flange face, after which the ends of the pipe and the flange are sometimes faced off in a lathe. Steel flanges are also welded to pipe and loose flanges are used by flanging over the pipe ends. When flanges are called for, and no method of attaching is stated, screwed flanges are always furnished.

Leaded Joints. For water pipe which does not have to stand very high pressures leaded joints are often used. The most common leaded joints are the Converse Lock Joint* and the Matheson Joint. Converse Joint is made by means of a special cast-iron coupling or hub which has a groove on each end extending around just inside of the end of the coupling, and two tee-shaped grooves on each end a short distance in from the circular groove. The pipe has two holes punched a short distance from the end on opposite sides into which rivets are driven. In making up this joint, the heads of the rivets slip into the tee-shaped slots of the hub, and the pipe is turned slightly, thus holding the pipe from pulling out of the hub endwise. This joint is then made tight by pouring lead into the circular slot and calking. The Matheson Joint† is another type of lead joint used for water or gas.

Working Pressures. All valves and fittings are classified, as a rule, under five general headings: low pressure, standard, medium pressure, extra heavy, and hydraulic, which are almost universally understood to represent the following working pressures:

Low Pressure — suitable for working steam pressures up to 25 pounds per square inch.

Standard — suitable for working steam pressures up to 125 pounds per square inch.

* See pages 84 and 108. † See pages 84 and 107.

Medium Pressure — suitable for working steam pressures from 125 pounds to 175 pounds per square inch.

Extra Heavy — suitable for working steam pressures from 175 pounds to 250 pounds per square inch.

Hydraulic — suitable for high pressure water up to 800 pounds pressure per square inch.

Water Hammer. When selecting valves and fittings, the possibility of shock or strain due to water hammer, in excess of the average working pressure of the line or system, should be considered. Many valves and fittings, installed where the working pressure under normal conditions would be low, have failed because of a pressure due to water hammer. This danger can be avoided by proper cushioning of the line (see page 284).

Expansion and Contraction. Expansion and contraction should be provided for in all installations, especially steam, by the use of an expansion joint, expansion bend, or other approved device. For table of expansion and contraction, see page 347.

Thread Gage. All valves and fittings are regularly furnished, threaded or tapped to the Briggs Standard Gage, which is the same as used for pipe threads. The threading is accurate to gage within ordinary limits of variation. (For article concerning Briggs Standard Threads see page 208.)

Nipples. Nipples are made in all sizes from ⅛ inch to 12 inches inclusive, in all lengths, either black or galvanized, and regular right-hand or right- and left-hand threads. (For table of nipples see pages 171–172.)

In the case of Long Screws or Tank Nipples, they should be made of extra heavy pipe because there is less danger of crushing or splitting them when screwing up.

Screwed Fittings — Malleable Iron. Malleable Iron Fittings are made in Standard, Extra Heavy and Hydraulic.

The Standard Malleable Iron Fittings are made in both plain and beaded.

The Plain Standard Malleable Iron Fittings are generally used for low pressure gas and water, as in house plumbing and railing work, and the beaded is the standard steam, air, gas, or oil fitting.

The Beaded Fittings are made in sizes from ⅛ inch to 8 inches inclusive, and in 4 inches and smaller in nearly every useful combination of openings. Sizes larger than 4 inches are not usually made reducing except by means of bushing.

The Extra Heavy and Hydraulic Malleable Iron Fittings are usually flat bead, or Banded, and Standard Malleable Iron Fittings with a flat bead are also coming into use.

Screwed Fittings — Cast Iron. Cast-Iron Screwed Fittings are made in Standard and Extra Heavy in sizes ¼ inch to 12 inches inclusive. However, it is not considered good practice to use screwed fittings of any kind in sizes larger than 6 inches.

Flanged Fittings. Flanged fittings are generally made only in sizes 2 inches and larger, and in four weights; namely, Low Pressure, Standard, Extra Heavy, and Hydraulic. The flanges of the Low Pressure and Standard are the same, with the exception of the flange thickness, which is less on the low pressure. These flanges are known as the American Society of Mechanical Engineers or Master Steam Fitters' Standard (see page 176).

The flanges of Extra Heavy fittings are what is known as the Manufacturers' Standard, or that adopted by leading valve and fitting manufacturers in 1901.

There is no recognized standard for flanges in Hydraulic work.

Unions. Unions are usually classified under two headings, Nut Unions and Flange Unions. The Nut Unions are commonly used in sizes 2 inches and smaller and Flange Unions in sizes larger than 2 inches. However, many manufacturers make Nut Unions as large as 4 inches and Flange Unions smaller than 2 inches.

Nut Unions are made in Malleable Iron, Brass and Malleable Iron, and all Brass. The all Malleable Iron Union (Lip Union) is the standard Malleable Union of the trade and requires a gasket. The Brass and Malleable Iron Union (known as the "Kewanee" Union) is a much better union because no gasket is required, and there is no possibility of the parts rusting together. The pipe end of the "Kewanee" Union which carries an external thread, called the thread end, upon which the nut or ring screws, is made of brass, and the other pipe end (called the bottom) and nut or ring are made of Malleable Iron. The seat formed by the Brass and Iron Pipe ends when brought together is truly spherical, and the harder iron is sure to make a perfect joint with the softer brass.

When selecting a Brass and Malleable Union, one with inserted brass pieces should be avoided. These inserts are generally rolled in, and frequently become loose under varying expansion and contraction; or when disconnection is attempted the nut and thread end are firmly corroded together.

All Brass Unions are made with a spherical or conical seat, no gaskets being required. The finished all Brass Union is often used where showy work is desired, such as oil piping for engines, etc.

Flange Unions are made of both cast iron and malleable iron in three weights, Standard, Extra Heavy, and Hydraulic.

Valves and Cocks. The most common means for regulating the flow of fluids in pipes is by means of valves and cocks, the valves being preferred because of the easier operation and greater reliability. The common types of valves are Straightway or Gate, Globe, and Angle. While the use of Globe Valves is still advised by some engineers, yet it is becoming more thoroughly appreciated every day that a straightway valve should be preferred, for many reasons, in most installations. One of the principal reasons for not using a globe valve is the resistance which it offers to the flow of any fluid. It is considered that a globe valve at its best offers 50 per cent more resistance to the flow of steam or other

fluids than a right-angled elbow. There are, however, some kinds of service where a globe valve is preferable, and many where an angle valve is an absolute necessity.

Gate or Straightway Valves. Gate or Straightway Valves are made in Low Pressure, Standard, Medium Pressure, Extra Heavy, and Hydraulic, in both brass and iron body. Gate Valves for superheated steam have also been made of all iron or steel castings. Brass valves are regularly made in sizes as large as 3 inches, and iron body Gate Valves are regularly made as follows:

Low Pressure	12 inches to 48 inches inclusive.
Standard	2 inches to 30 inches inclusive.
Medium Pressure	2 inches to 18 inches inclusive.
Extra Heavy	1¼ inches to 24 inches inclusive.
Hydraulic	1½ inches to 12 inches inclusive.

Globe and Angle Valves. Globe and Angle Valves are made in Standard, Medium Pressure, Extra Heavy and Hydraulic, in both brass and iron body, except Hydraulic, which are generally made in brass only. Many manufacturers make a Globe and Angle Valve known as Light Standard or Competition Valve, but it is not recommended for any work except the lowest pressures, or where the valve will not be often opened or closed.

Standard Brass Globe and Angle Valves are regularly made in sizes ⅛ inch to 4 inches inclusive, Medium Pressure ¼ inch to 3 inches inclusive, Extra Heavy ½ inch to 3 inches inclusive, and Hydraulic ½ inch to 2 inches inclusive.

The Standard and Extra Heavy Iron Body Globe and Angle Valves are regularly made in sizes from 2 inches to 12 inches inclusive.

Check Valves. Check Valves are regularly made in Standard, Medium Pressure, Extra Heavy and Hydraulic, in both brass and iron body. The brass Check Valves are regularly made in sizes from ⅛ inch to 4 inches inclusive, and the iron body Check Valves in sizes 2 inches to 12 inches inclusive.

Cocks. Cocks are generally designated under two headings, Steam and Gas, and are made in both brass and iron body. The brass are regularly made in sizes from ¼ inch to 3 inches inclusive, and the iron body in sizes from ½ inch to 6 inches inclusive.

Blast Furnace Fittings. Under this heading may be classified Tuyere Cocks, Tuyere Unions, and Universal Unions, which are very common fittings in blast furnace piping, and are always made of brass on account of the ease in disconnecting, greater reliability of metal, and resistance to corrosion from the impurities in the water, such as sulphuric acid.

NOTE.—A special catalogue, showing fittings, valves, etc., has been issued.

Wrought Pipe Nipples — Black and Galvanized

Fig. 60

Fig. 61

Threaded Right Hand

Size	Length															Threads per inch
	Close	Short	Long				Extra long									
⅛	¾	1½	2	2½	3	3½	4	5	6	7	8	9	10	11	12	27
¼	⅞	1½	2	2½	3	3½	4	5	6	7	8	9	10	11	12	18
⅜	1	1½	2	2½	3	3½	4	5	6	7	8	9	10	11	12	18
½	1⅛	1½	2	2½	3	3½	4	5	6	7	8	9	10	11	12	14
¾	1⅜	2	2½	3	3½	4		5	6	7	8	9	10	11	12	14
1	1½	2	2½	3	3½	4		5	6	7	8	9	10	11	12	11½
1¼	1⅝	2½	3	3½	4	4½		5	6	7	8	9	10	11	12	11½
1½	1¾	2½	3	3½	4	4½		5	6	7	8	9	10	11	12	11½
2	1⅞	2½	3	3½	4	4½		5	6	7	8	9	10	11	12	11½
2½	2½	3	3½	4	4½	5			6	7	8	9	10	11	12	8 and 11½
3	2⅝	3	3½	4	4½	5			6	7	8	9	10	11	12	8 and 11½
3½	2¾	4	4½	5	5½	6	.	.	..	7	8	9	10	11	12	8
4	3	4	4½	5	5½	6	.	...	...	7	8	9	10	11	12	8
4½	3	4	4½	5	5½	6				7	8	9	10	11	12	8
5	3¼	4½	5	5½	6	6½		..	.	7	8	9	10	11	12	8
6	3½	4½	5	5½	6	6½		.	.	7	8	9	10	11	12	8
7	3¼	5		..	....	6			.	7	8	9	10	11	12	8
8	3½	5	.	...	...	6	.	...		7	8	9	10	11	12	8
9	4	5		..	6	8				..	.	9	10	11	12	8
10	4	5	..	...	6	8				.	..	9	10	11	12	8
11	4	5	...	....	6	8		.	..		...	9	10	11	12	8
12	4	5	..	.	6	8		.				9	10	11	12	8

Assorted close and short nipples will always be shipped, unless otherwise ordered.

Nipples also made from Extra Strong Pipe.

Nipples longer than 12 inches can be furnished when ordered.

Taper of threads is ¾ inch diameter per foot length for all sizes.

Nipples larger than 3 inch pipe and longer than 12 inches are considered as cut pipe and can be furnished when ordered.

2½ inch and 3 inch nipples will be furnished 8 threads unless otherwise ordered.

All dimensions given in inches.

Wrought Pipe Nipples — Black and Galvanized

Fig. 62

Threaded Right and Left Hand

Size	Length														Threads per inch
	Short	Long				Extra long									
⅛	1½	2	2½	3	3½	4	5	6	7	8	9	10	11	12	27
¼	1½	2	2½	3	3½	4	5	6	7	8	9	10	11	12	18
⅜	1½	2	2½	3	3½	4	5	6	7	8	9	10	11	12	18
½	1½	2	2½	3	3½	4	5	6	7	8	9	10	11	12	14
¾	2	2½	3	3½	4	...	5	6	7	8	9	10	11	12	14
1	2	2½	3	3½	4	...	5	6	7	8	9	10	11	12	11½
1¼	2½	3	3½	4	4½	...	5	6	7	8	9	10	11	12	11½
1½	2½	3	3½	4	4½	...	5	6	7	8	9	10	11	12	11½
2	2½	3	3½	4	4½	...	5	6	7	8	9	10	11	12	11½
2½	3	3½	4	4½	5	...	...	6	7	8	9	10	11	12	8
3	3	3½	4	4½	5	...	...	6	7	8	9	10	11	12	8
3½	4	4½	5	5½	6	...	...	...	7	8	9	10	11	12	8
4	4	4½	5	5½	6	...	...	...	7	8	9	10	11	12	8

Nipples also made from Extra Strong Pipe.

Nipples longer than 12 inches can be furnished when ordered.

Nipples larger than 3-inch pipe and longer than 12 inches are considered as cut pipe and can be furnished when ordered.

Taper of threads is ¾ inch diameter per foot length for all sizes.

All dimensions given in inches.

Wrought Pipe — Long Screw Nipples — Black and Galvanized

Fig. 63

Threaded Right Hand

Size	¼	⅜	½	¾	1	1¼	1½	2	2½	3	3½	4
Standard length	2½	3	3½	4	4½	5	5½	6	7	8	8½	9
Threads per inch	18	18	14	14	11½	11½	11½	11½	8	8	8	8

Nipples made from Extra Strong Pipe.
All dimensions given in inches.
Long screws, longer than Standard can be made.
In ordering special lengths always specify the length of thread desired.

Wrought Pipe Tank Nipples — Black and Galvanized

Fig. 64

Threaded Right Hand

Size	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½	3	3½	4
Standard length	6	6	6	6	6	6	6	6	6	7	8	8½	9
Threads per inch	27	18	18	14	14	11½	11½	11½	11½	8 and 11½	8 and 11½	8	8

Nipples made from Extra Strong Pipe.
Nipples longer than Standard can be furnished when ordered.
All dimensions given in inches.
In ordering special lengths always specify the length of thread desired.

Wrought Casing Nipples

Fig. 65

Threaded Right Hand

Size	Length												
	Close	Short	Long				Extra long						
3	2½	3	3½	4	4½	5	6	7	8	9	10	11	12
3¼	2¾	4	4½	5	5½	6	...	7	8	9	10	11	12
3½	2¾	4	4½	5	5½	6	...	7	8	9	10	11	12
3¾	2¾	4	4½	5	5½	6	...	7	8	9	10	11	12
4	3	4	4½	5	5½	6	...	7	8	9	10	11	12
4¼	3	4	4½	5	5½	6	...	7	8	9	10	11	12
4½	3	4	4½	5	5½	6	...	7	8	9	10	11	12
4¾	3	4	4½	5	5½	6	...	7	8	9	10	11	12
5	3	4	4½	5	5½	6	...	7	8	9	10	11	12
5 3/16	...	...	5	5½	6	6½	...	7	8	9	10	11	12
5⅝	...	...	5	5½	6	6½	...	7	8	9	10	11	12
6¼	...	...	...	...	...	...	6	7	8	9	10	11	12
6⅝	...	...	...	...	...	...	6	7	8	9	10	11	12
7⅝	...	...	...	...	...	...	6	7	8	9	10	11	12
8¼	...	...	...	...	...	...	6	7	8	9	10	11	12
8⅝	...	...	...	...	...	...	...	7	8	9	10	11	12
9⅝	...	...	...	...	...	...	...	7	8	9	10	11	12
10¾	...	...	...	...	...	...		7	8	9	10	11	12

Made from lightest weight Standard Boston Casing and same number of threads per inch as shown on page 26, unless otherwise ordered.

Nipples longer than 12 inches can be furnished when ordered.

All dimensions given in inches.

Extra Heavy Pipe Flanges (Threaded)

Suitable for 250 Pounds Working Steam Pressure

Adopted by a Conference of Manufacturers, June 28, 1901

Pipe size		Flange			Bolts				Weight per pair
Internal diameter	External diameter	Outside diameter	Thickness	Length	Number	Size	Length	Circle	
2	2⅜	6½	⅞	1⅜	4	⅝	3	5	15
2½	2⅞	7½	1	1 7/16	4	¾	3½	5⅞	21
3	3½	8¼	1⅛	1 9/16	8	⅝	3½	6⅝	28
3½	4	9	1 3/16	1⅝	8	⅝	3½	7¼	34
4	4½	10	1¼	1¾	8	¾	4	7⅞	44
4½	5	10½	1 5/16	1 13/16	8	¾	4	8½	50
5	5 9/16	11	1⅜	1⅞	8	¾	4	9¼	56
6	6⅝	12½	1 7/16	2	12	¾	4½	10⅝	72
7	7⅝	14	1½	2 1/16	12	⅞	4½	11⅞	91
8	8⅝	15	1⅝	2 3/16	12	⅞	5	13	108
9	9⅝	16	1¾	2¼	12	⅞	5	14	126
10	10¾	17½	1⅞	2⅜	16	⅞	5½	15¼	155
11	11¾	18¾	2	2½	16	⅞	5½	16½	186
12	12¾	20	2	2 9/16	16	⅞	5½	17¾	209
13	14	22½	2⅛	2 11/16	20	⅞	6	20	288
14	15	23½	2 3/16	2 13/16	20	1	6	21	311
15	16	25	2¼	2⅞	20	1	6	22½	363
	18	27	2⅜	3 1/16	24	1	6½	24½	423
	20	29½	2½	3¼	24	1⅛	7	26¾	515
	22	31½	2⅝	3 7/16	28	1⅛	7	28¾	587
	24	34	2¾	3⅝	28	1⅛	7½	31¼	713

All dimensions given in inches.
All weights given in pounds.
Weights specified do not include bolts and gaskets.

Standard Pipe Flanges (Cast Iron, Threaded)

Adopted August, 1894, by a Committee of the Master Steam and Hot Water Fitters' Association, a Committee of the American Society of Mechanical Engineers, and the leading Valve and Fitting Manufacturers of the United States.

Pipe size		Flange			Bolts			
Internal diameter	External diameter	Outside diameter	Thickness	Width of Face	Number	Size	Length	Circle
2	2⅜	6	⅝	2	4	½ ⅝	2	4¾
2½	2⅞	7	11/16	2¼	4	½ ⅝	2¼	5½
3	3½	7½	¾	2¼	4	½ ⅝	2½	6
3½	4	8½	13/16	2½	4	½ ⅝	2½	7
4	4½	9	15/16	2½	4	⅝ ¾	2¾	7½
4½	5	9¼	15/16	2⅝	8	⅝ ¾	3	7¾
5	5 9/16	10	15/16	2½	8	⅝ ¾	3	8½
6	6⅝	11	1	2½	8	⅝ ¾	3	9½
7	7⅝	12½	1 1/16	2¾	8	⅝ ¾	3¼	10¾
8	8⅝	13½	1⅛	2¾	8	⅝ ¾	3½	11¾
9	9⅝	15	1⅛	3	12	⅝ ¾	3½	13¼
10	10¾	16	1 3/16	3	12	¾ ⅞	3⅝	14¼
12	12¾	19	1¼	3½	12	¾ ⅞	3¾	17
13	14	21	1⅜	3½	12	⅞ 1	4¼	18¾
14	15	22¼	1⅜	3⅝	16	⅞ 1	4¼	20
15	16	23½	1 7/16	3¾	16	⅞ 1	4¼	21¼
.....	18	25	1 9/16	3½	16	1 1⅛	4¾	22¾
.....	20	27½	1 11/16	3¾	20	1 1⅛	5	25
.....	22	29½	1 13/16	3¾	20	1 1¼	5½	27¼
.....	24	31½ 32	1¼ 1⅞	3¾ 4	20	1 1¼	5½	29¼ 29½
.....	26	33¾ 34¼	1⅜ 2	3⅞ 4⅛	24	1 1¼	5¾	31¼ 31¾
.....	28	36 36½	1 7/16 2 1/16	4 4¼	28	1 1¼	6	33½ 34
.....	30	38 38¾	1½ 2⅛	4 4⅜	28	1⅛ 1⅜	6¼	35½ 36

These flanges in the heavier bolting are used in general practice for pressures up to 125 pounds per square inch. For greater pressures see table, page 175, of extra heavy flanges adopted by a Conference of Manufacturers, June 28, 1901.

All dimensions given in inches.

HAND RAILINGS

The use of pipe and fittings for hand railings around area ways, on stairs, for office enclosures with gates and for permanent ladders, is illustrated by the following set of cuts, which are typical of many installations which might be made. The construction of hand railings of such materials commends itself, first, on the ground of durability due to material used; second, neatness of design and detail; third, safety due to strength; and fourth, cheapness of construction. The illustrations illustrate methods of assembling, which can be differentiated in a great many ways, but which have been found successful and economical.

Regular railing fittings, such as shown by figures H-164 to H-172 inclusive, are furnished recessed, so that all short threads will be covered. Other railing fittings may be furnished in the same manner. Fittings of special angles can also be furnished when required, at special prices, but it is our experience that the regular patterns can be used in almost all cases, regardless of the angles involved, either by bending the pipe, as in Fig. 71, or by the use of extra fittings, as in Fig. 72.

The numbers on the illustrations with the letter "H" in front refer to National Tube Company's catalogue H, issue 1909.

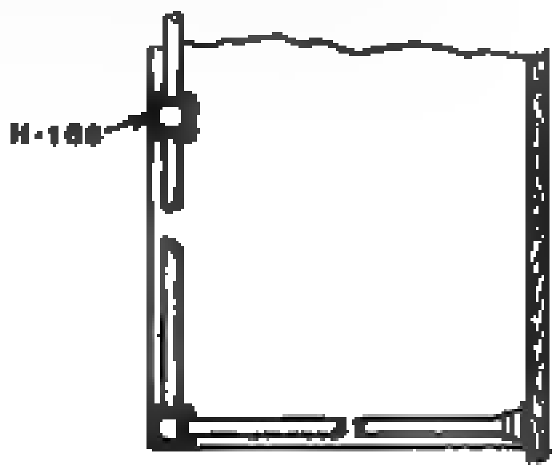


Fig. 66

NOTE. All threads right-hand. Thread double length where indicated. Numbers given refer to catalogue numbers.

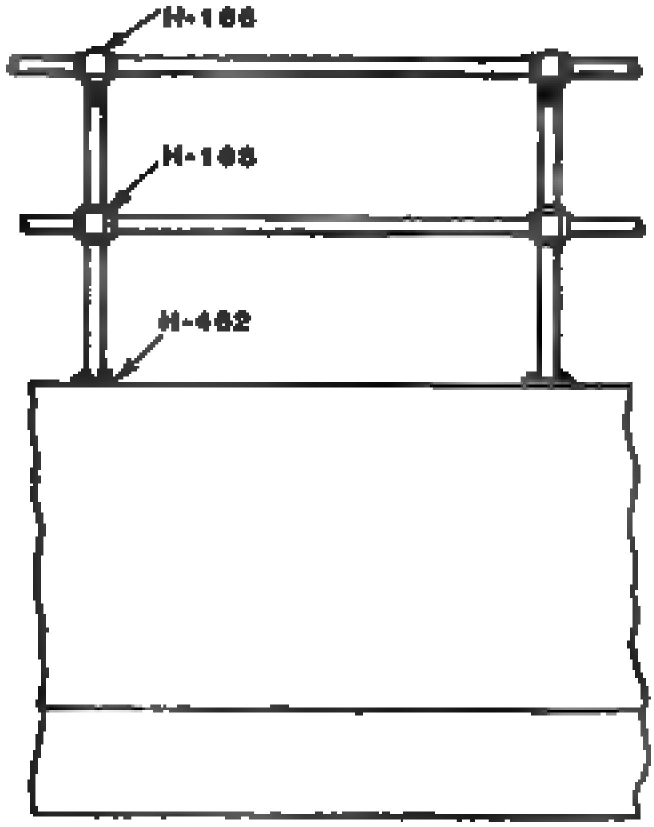


Fig. 67

NOTE. All threads right-hand. Thread double length where indicated. Numbers given refer to catalogue numbers.

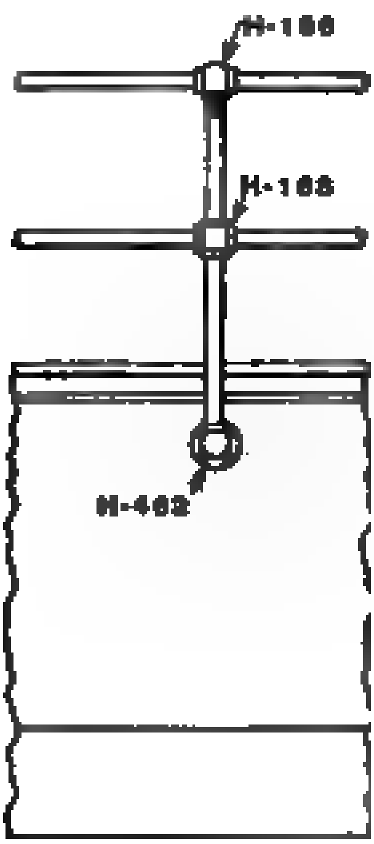


Fig. 68

NOTE. All threads right-hand. Thread double length where indicated. Numbers given refer to catalogue numbers.

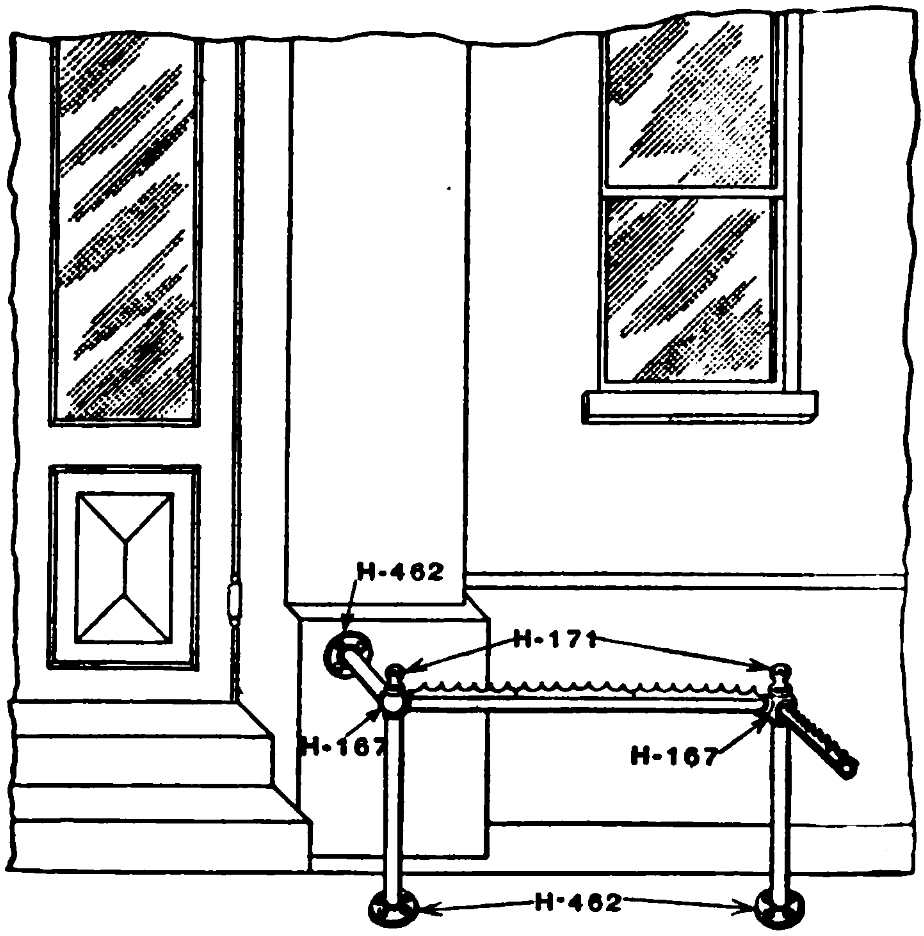


Fig. 69

Note. All threads right-hand. Numbers given refer to catalogue numbers.

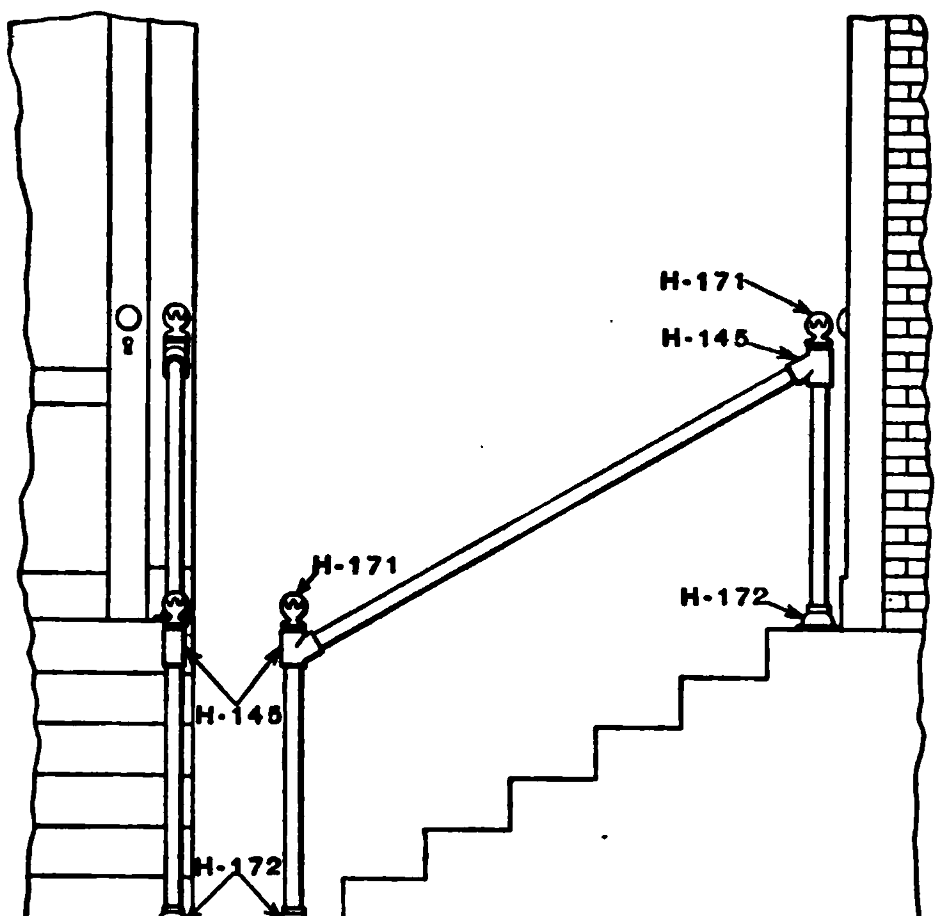


Fig. 70

Note. Suitable for steps at 30° angle. All threads right-hand. Numbers given refer to catalogue numbers.

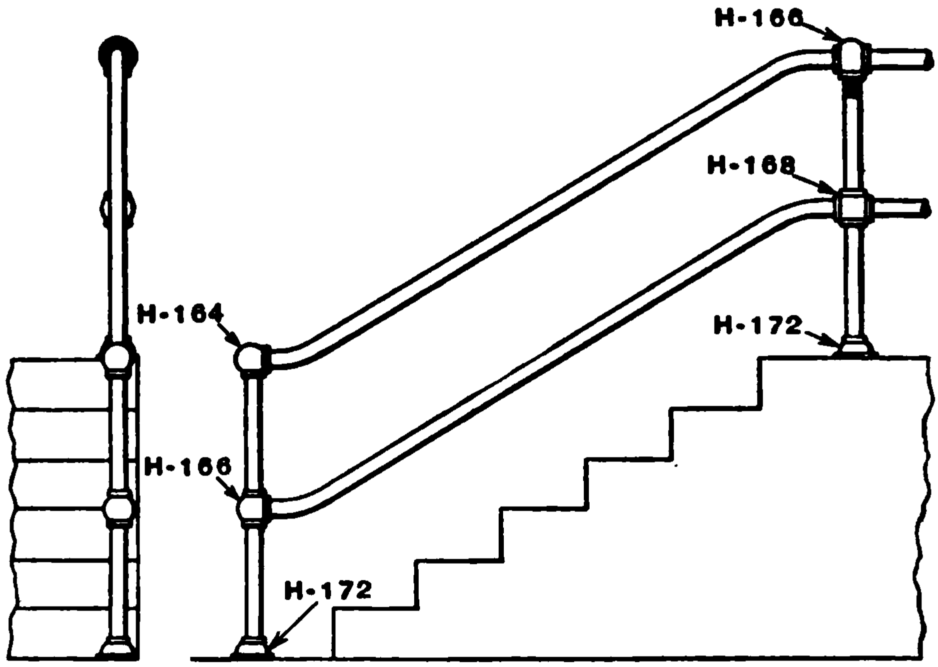


Fig. 71

NOTE. Standard fittings used and pipes bent to suit any angle of steps. All threads right-hand. Thread double length where indicated. Numbers given refer to catalogue numbers.

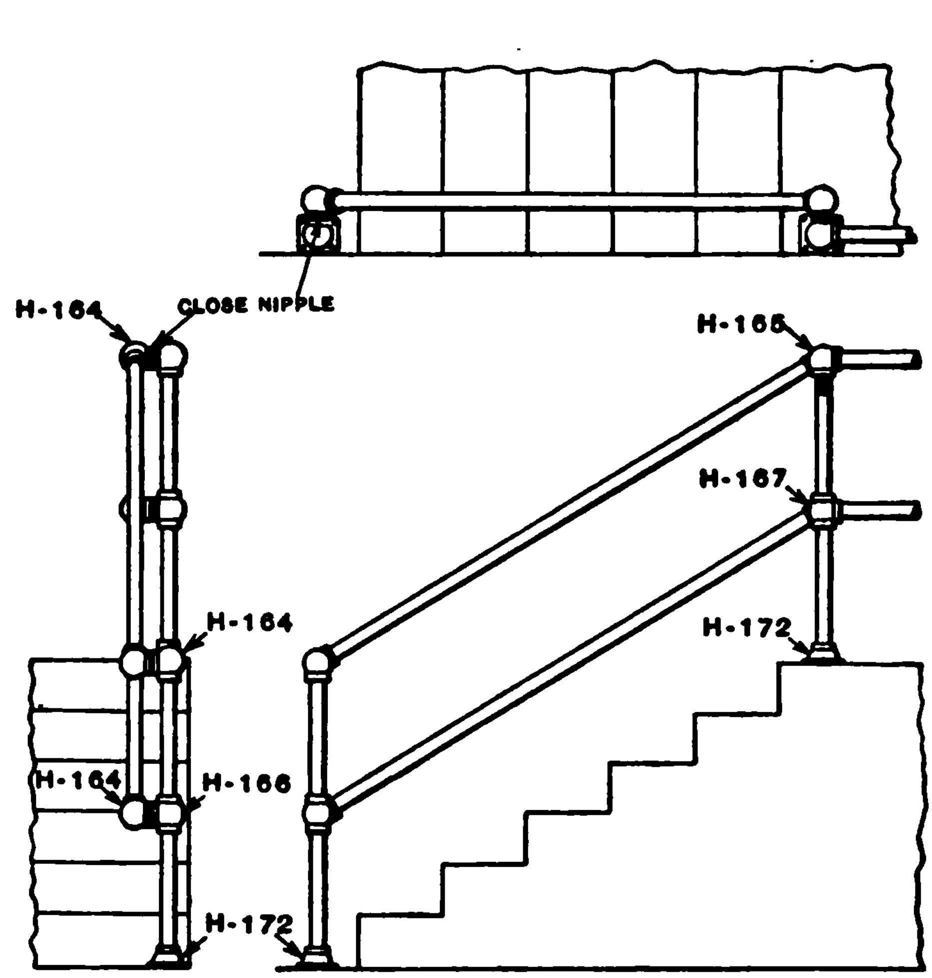


Fig. 72

NOTE. Standard fittings are suitable for any angle of steps. All threads right-hand. Thread double length where indicated. Numbers given refer to catalogue numbers.

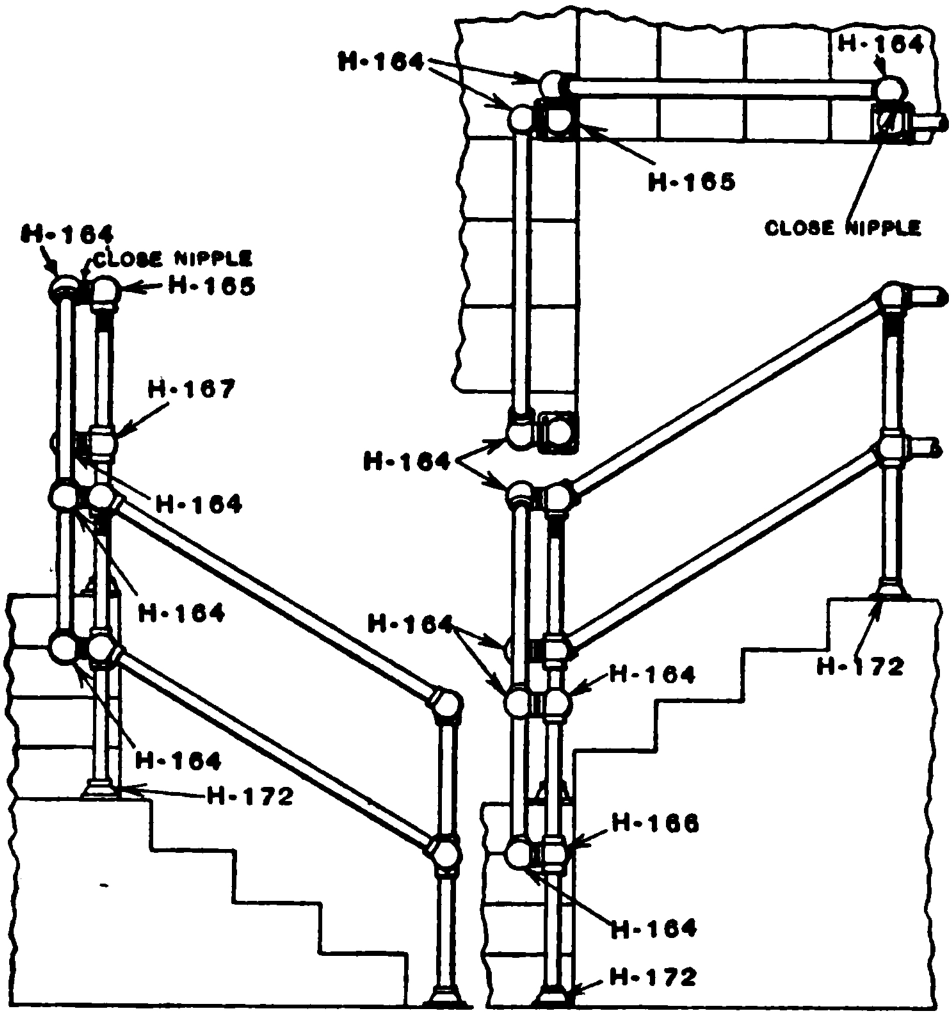


Fig. 73

NOTE. Standard fittings are suitable for any angle of steps. All threads right-hand. Thread double length where indicated. Numbers given refer to catalogue number.

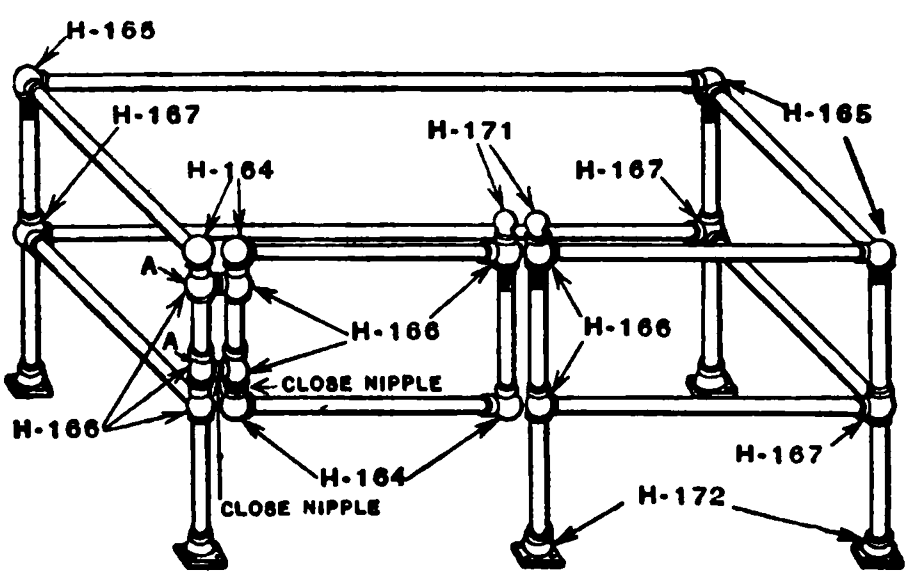


Fig. 74

NOTE. Fittings marked "A" are bored to turn on pipes for hinges. All threads right-hand. Thread double length where indicated. Numbers given refer to catalogue number.

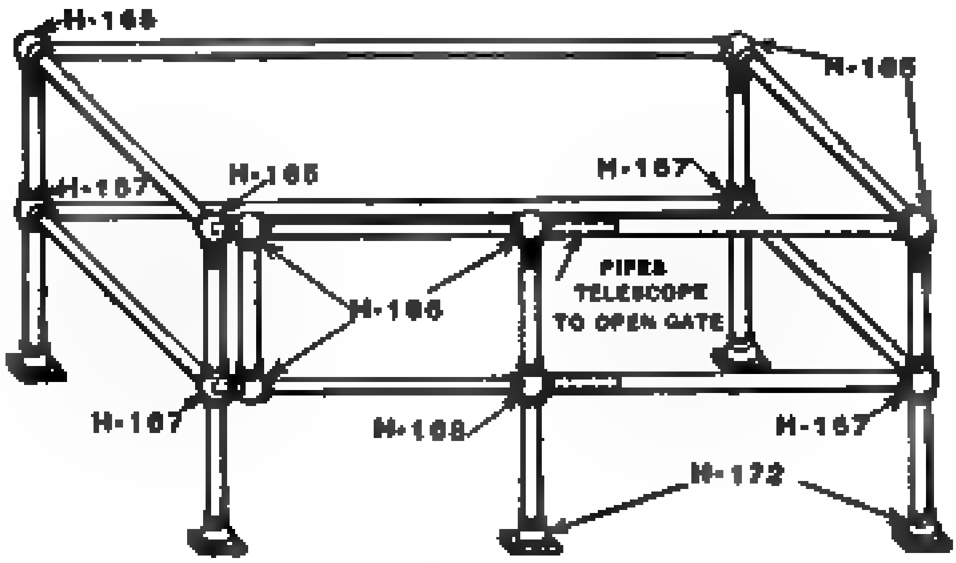


Fig. 75

NOTE. All threads right-hand. Thread double length where indicated. Numbers given refer to catalogue number.

Fig. 76

NOTE. All threads right-hand. Thread double length where indicated. Numbers given refer to catalogue numbers.

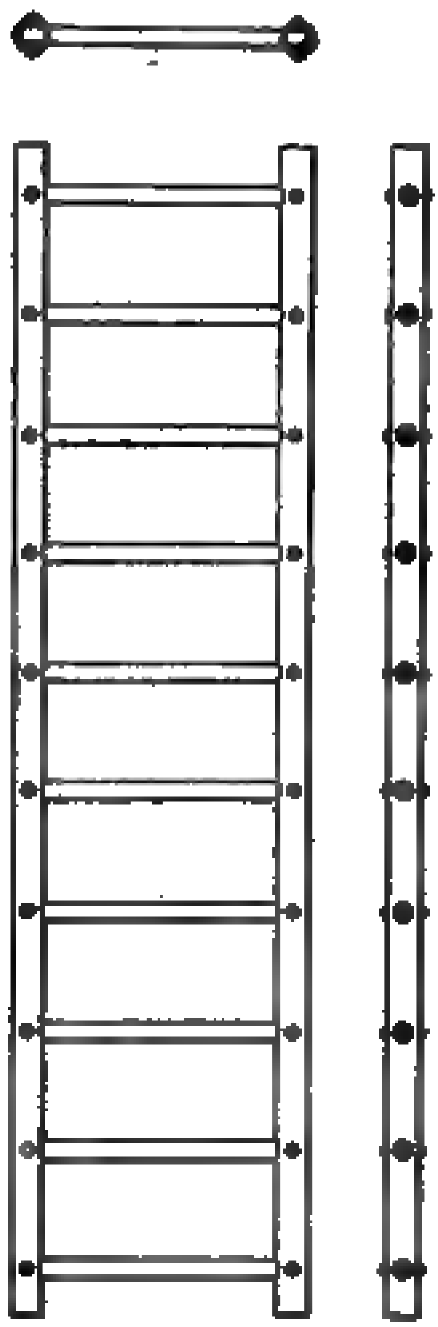


Fig. 77

Round Pipe Rungs
Round Pipe Runners

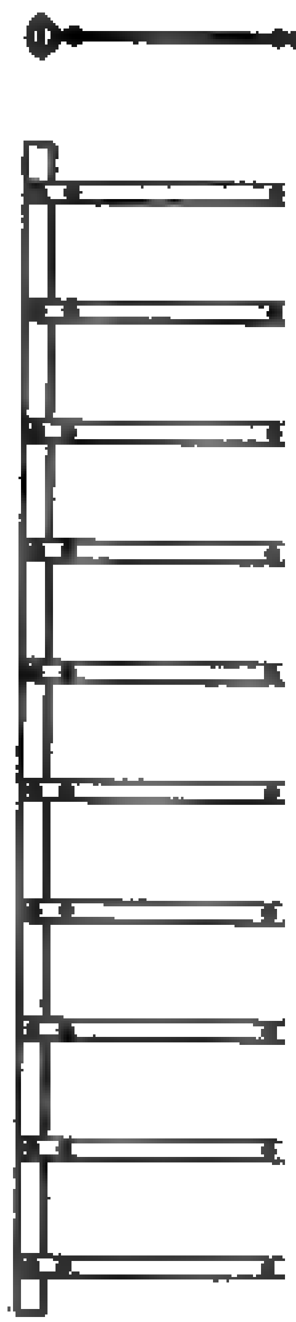


Fig 78

Flat Bar Rungs
Round Pipe Runners

Typical Pipe Ladders

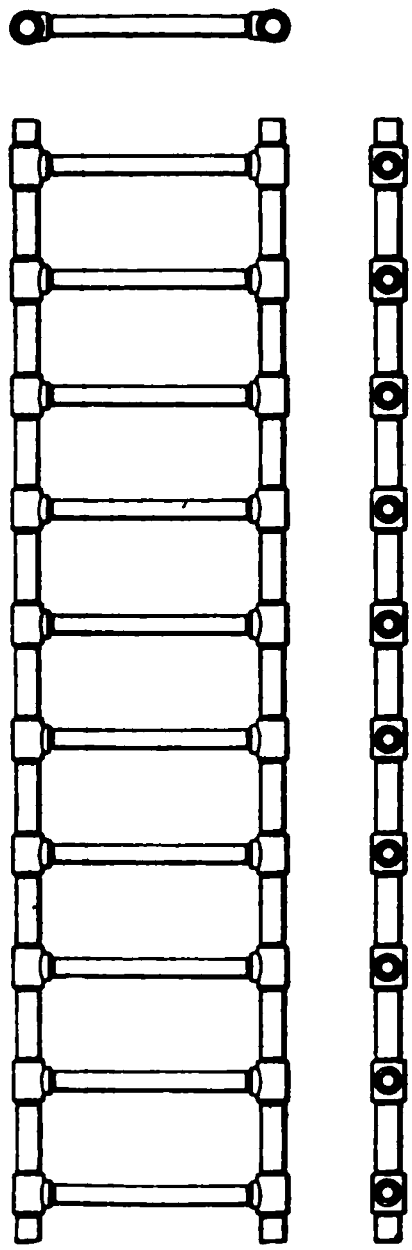


Fig. 79

Round Pipe Rungs
Round Pipe Runners

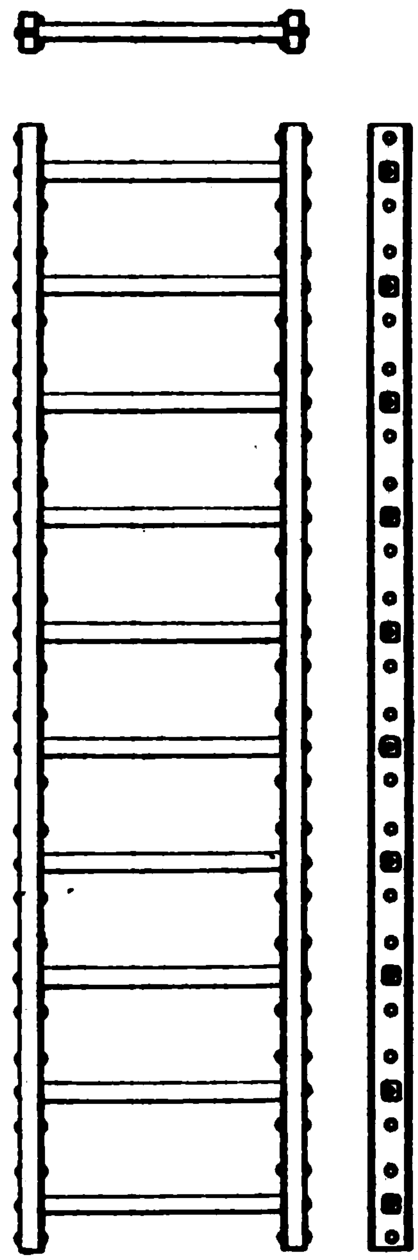


Fig. 80

Square Pipe Rungs
Rectangular Pipe Runners

Typical Pipe Ladders

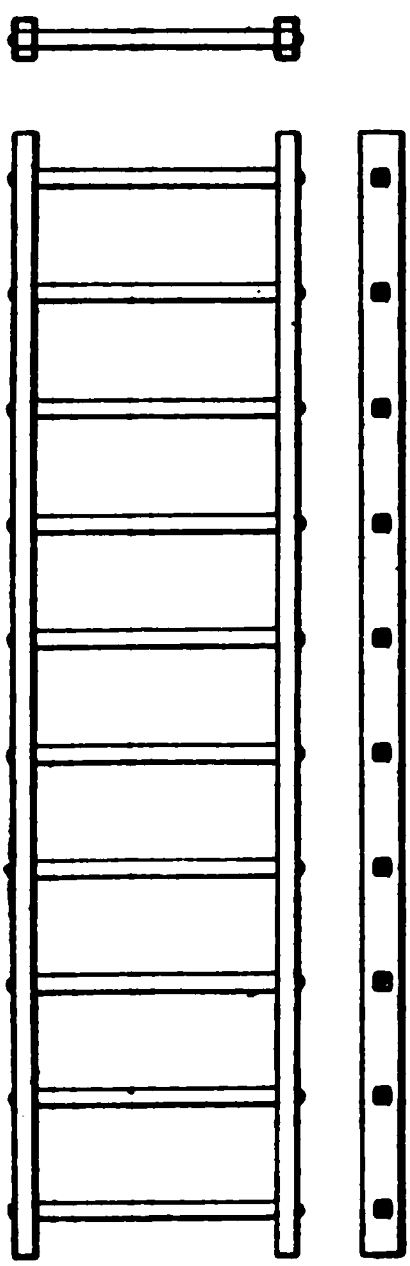


Fig. 81

Square Pipe Rungs
Rectangular Pipe Runners

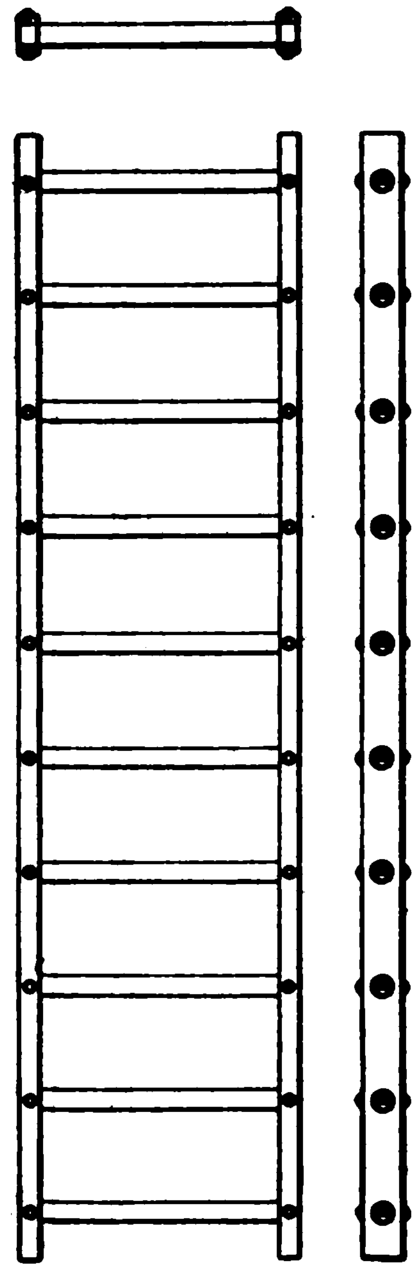


Fig. 82

Round Pipe Rungs
Rectangular Pipe Runners

Typical Pipe Ladders

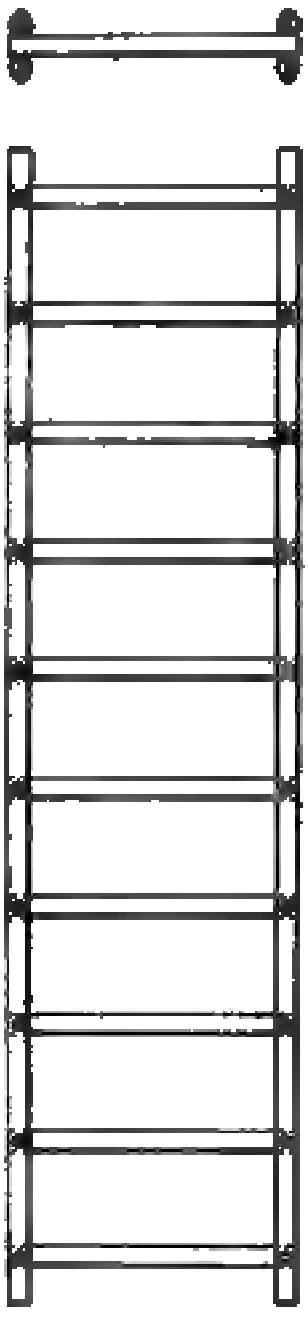


Fig. 83

Round Pipe Rungs
Round Pipe Runners

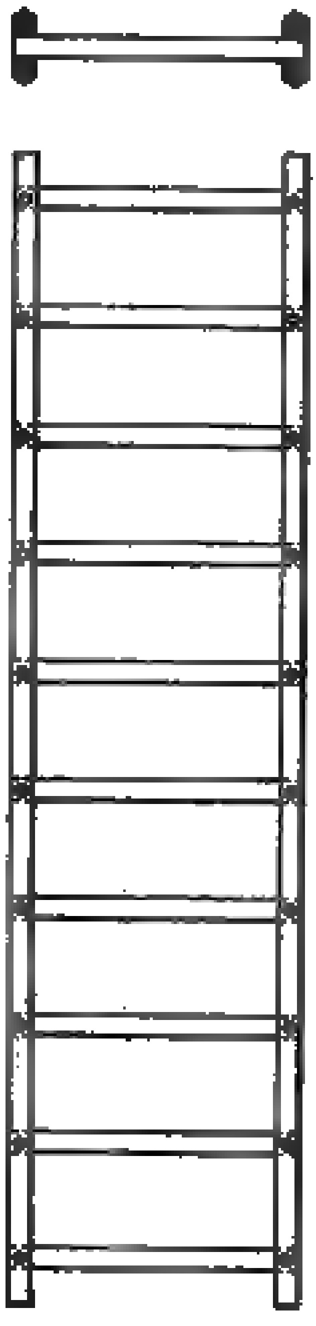


Fig. 84

Square Pipe Rungs
Square Pipe Runners

Typical Pipe Ladders

WORKING BARRELS

The working barrels, sizes and weights of which are given in table shown, are manufactured from specially made lap-welded pipe. The steel from which these lap-welded pipes are made is of a special composition with a view to obtaining a hard, smooth surface in the finished working barrel.

The making of the working barrel from a lap-welded pipe is accomplished by a special process consisting of several cold-drawing operations. These cold-drawing operations make the inside surface of the working barrel extremely smooth and bright; besides that it still further hardens the surface of the working barrel, over and above the hardness already established in the especially prepared lap-welded pipe.

This process of manufacturing working barrels makes them especially adapted and suited for the hard service to which they are subjected in the oil fields.

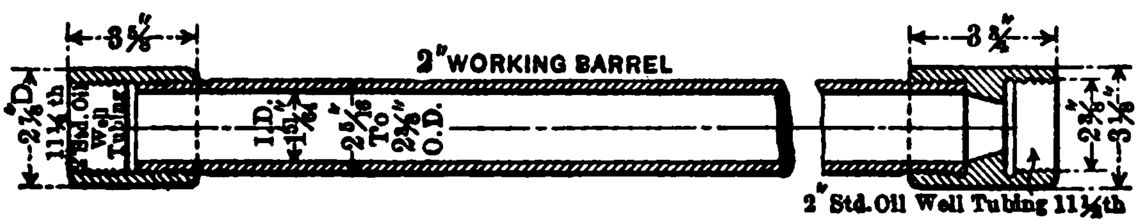


Fig. 85

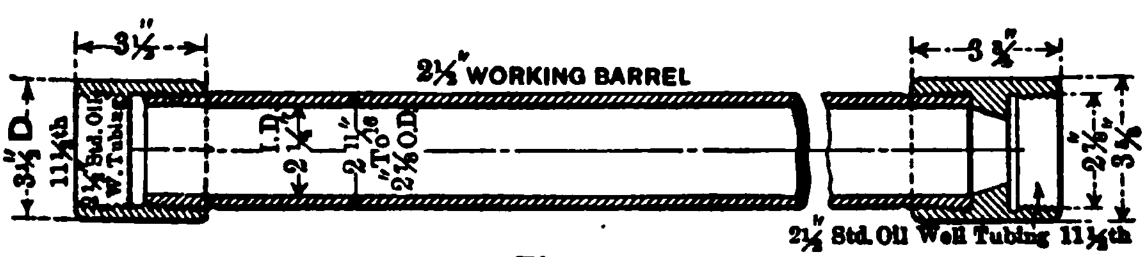


Fig. 86

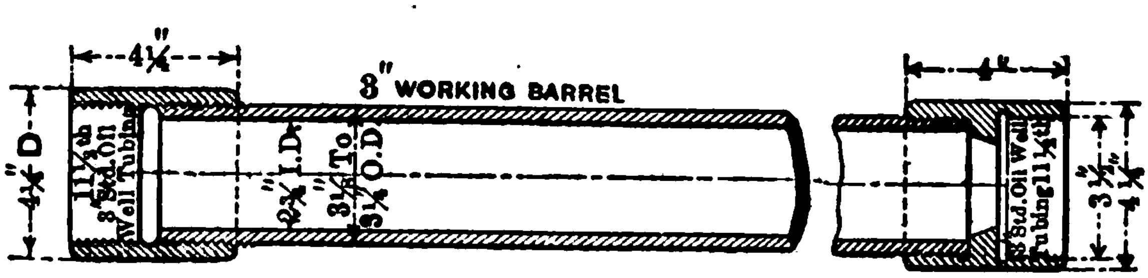


Fig. 87

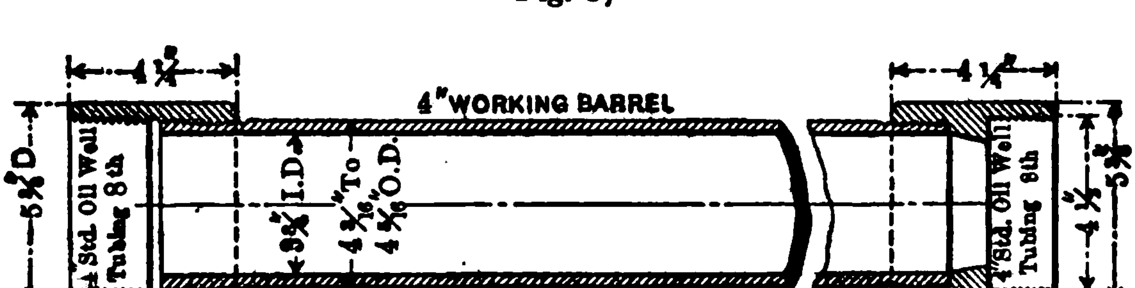


Fig. 88

Note. All Working Barrels are threaded 14 threads per inch.

Table of Lengths and Weights of Working Barrels

Lengths of Working Barrels	2-inch Barrel			2½-inch Barrel			3-inch Barrel			4-inch Barrel		
	Nominal weights of Working Barrels, complete with both couplings	Weight of upper coupling	Weight of lower coupling	Nominal weights of Working Barrels, complete with both couplings	Weight of upper coupling	Weight of lower coupling	Nominal weights of Working Barrels, complete with both couplings	Weight of upper coupling	Weight of lower coupling	Nominal weights of Working Barrels, complete with both couplings	Weight of upper coupling	Weight of lower coupling
Ft. In.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
4-0	29	2.5	3.5	31	3.5	5	44	5.5	6.5	66	8	9
4-6	34	....	....	35	....	....	48	....	....	72	....	....
5-0	37	....	....	38	....	....	53	....	....	78	....	....
5-6	40	....	....	41	....	....	57	....	....	84	....	....
6-0	43	....	....	45	....	....	61	....	....	90	....	....
6-6	46	....	....	47	....	....	65	....	....	96	....	....
7-0	49	....	....	50	....	....	69	....	....	103	....	....
7-6	53	....	....	54	....	....	74	....	....	109	....	....
8-0	56	....	....	57	....	....	77	....	....	115	....	....
9-0	63	....	....	64	....	....	85	....	....	127	....	....
10-0	70	....	....	71	....	....	93	....	....	139	....	....

SEAMLESS CYLINDERS

National Tube Company manufactures seamless cylinders for a variety of purposes: containers for oxygen, carbonic acid, air, etc. A wide range of sizes is produced, varying from a few pounds in weight up to 18 and 20 inches in diameter with ¾-inch wall and 12 to 14 feet long.

The smaller cylinders are manufactured from a seamless hot-rolled or cold-drawn tube, one end being forged to form the neck, and the other end being closed in for the bottom.

The larger cylinders are made from a flat plate, cupped and hot-drawn into a cylindrical shell. The closed end of the shell, remaining from the cupping process, forms the bottom of the container; the open end is forged to form the neck.

The material used for making cylinders is basic open-hearth steel of analysis to give desired physical properties; low-medium, high-carbon and nickel steels, also chrome-vanadium steels, are regularly furnished when desired.

NOTE. See standard specifications for seamless cylinders.

CYLINDER HEADS; THEIR STRENGTH, ETC.

The ends of pipes or tubes may have heads put in or formed with them in order to produce cylinders. Commercial considerations of quantity of cylinders, cost of manufacture, handling, etc., affect the selection of the design, often to greater extent than do engineering considerations. A design that would be permissible and cheap on 10 000 heads might be of prohibitive cost on one head. The ordinary shapes of heads are here shown:

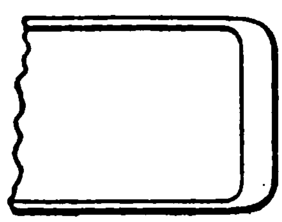


Fig. 89

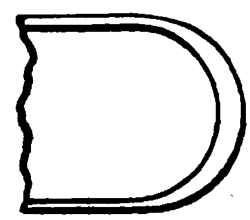


Fig. 90

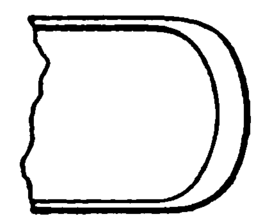


Fig. 91

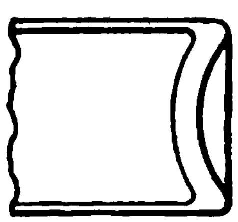


Fig. 92

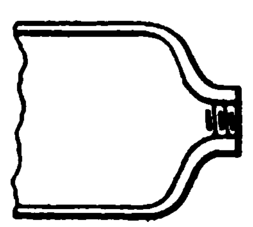


Fig. 93

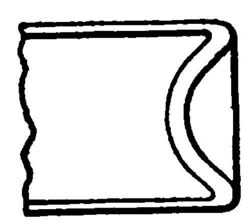


Fig. 94

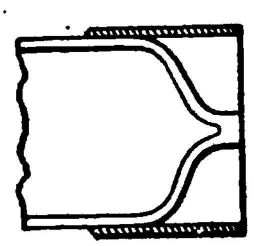


Fig. 95

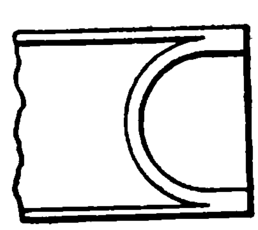


Fig. 96

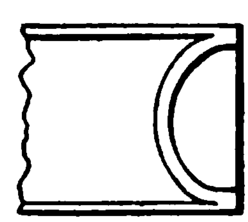


Fig. 97

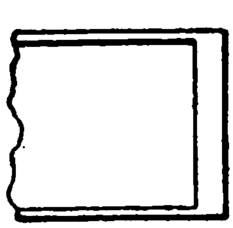


Fig. 98

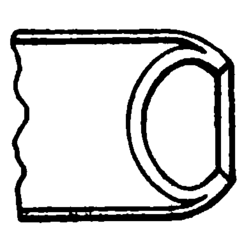


Fig. 99

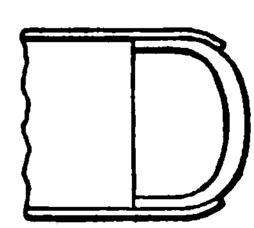


Fig. 100

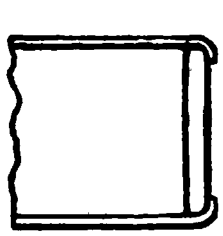


Fig. 101

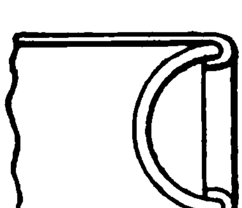


Fig. 102

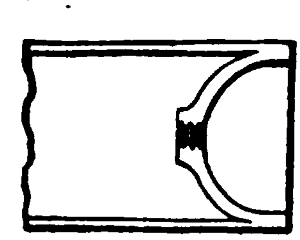


Fig. 103

Figs. 89, 98, and 101 show "*flat heads.*" Fig. 89 shows the seamless shape which is frequently used on cylinders of large diameters over 10 inches, when the cylinders are required to stand upright. Fig. 98 shows a head welded in lap-weld pipe. Such is desirable at times because the thick heads permit tapping for connections. When only a few cylinders are wanted such heads are relatively cheap. Fig. 101 shows style of welded heads used on annealing pots.

Figs. 90 and 91 show heads that are called "*Round*" or "*Spherical*" on seamless cylinders, while Fig. 100 shows heads that are called "*Bumped*" in the case of lap-weld cylinders. Bumped heads are brazed in. This style of heads is used on cylinders that are not required to stand upright.

Figs. 92, 94, 95, 96, 97, 102, and 103 show styles of heads that are applied to cylinders that are required to stand upright. Figs. 92, 94, and 95 are used on seamless cylinders up to 10-inch diameter. Figs. 96 and 97 may be used on any size of lap-weld cylinders. Fig. 102 is practically restricted in use to small sizes and is frequently made tight by means of hard or soft solder.

Fig. 93 shows what may be called the "*Standard*" neck, end, or head used on all seamless cylinders.

Fig. 99 shows a "*converged*" form of ends, which are so formed in order to prevent the fingers from slipping off when handling the cylinders. This shape does not affect or increase the strength or security of the heads to any calculable extent.

Thin heads that must be drilled and tapped usually require reinforcement at the holes. A common form of such is shown in Fig. 103, which illustrates what is called a welded "*boss*" or "*pop.*"

Figs. 90 and 91 show heads that are usually the consequent product from the plates of which the cylinder is drawn, but many are produced by a spinning operation from the material of the tubes, and so permits a cylinder to be made from "plain-end" tube. Using lap-weld pipe this shape may be made by swaging down to a shape somewhat like Fig. 95, and then welding, or welding in a plug.

The strength of heads is usually determined, in the case of round, spherical, or bumped heads (Figs. 90, 91, and 100), by the simple approximate rule for spheres subjected to internal pressure: i.e.,

$$pD = 4\,TS,$$

which is suitable in such cases, as $pd = 2\,ts$ is suitable for pipes. Therefore, for one pressure and one fiber stress the thickness of a sphere would be half the thickness of a cylinder of same diameter, or for equal thickness the radius of the sphere would equal the diameter of the pipe. The same rule may be applied to the shape per Figs. 93 and 95, but the radius of curvature of such shape is usually determined by the swaging process by which it is produced. That process also invariably thickens the material toward the neck.

The cupped heads like Fig. 91, having the thickness of the plate from which the tube is made, usually can stand having the head dished in, without the head being weaker than the shell.

The strength of welded dished heads (Figs. 96, 97, 99, and 102) is less understood, but the marine-inspection laws usually allow them to carry 6/10 the pressure that may be put on bumped heads. Expressed otherwise, the thickness of dished heads by such rules must be 1⅔ times the thickness of bumped heads. Thus

$$T = \frac{pD}{4s}\left(1\,\frac{2}{3}\right) = \frac{5\,pD}{12\,s} = \frac{5\,pR}{6\,s}.$$

Assume that steel of good welding quality may be stressed to $s =$ 20 000 pounds per square inch by test pressure $= p$; then an approximate solution gives the thickness of heads stated in the following table for value of R and p (in inches and pounds per square inch). $R =$ radius of curvature of spherical dished heads.

Table of Thickness of Dished Heads

Radius R	Test pressure p						
	500	700	1000	1500	2000	2500	3000
2	.042	.058	.083	.13	.17	.21	.25
3	.063	.088	.13	.19	.25	.31	.38
4	.083	.12	.17	.25	.33	.42	.50
5	.10	.15	.21	.31	.42	.52	.63
6	.13	.18	.25	.38	.50	.63	.75
8	.17	.23	.33	.50	.67	.83	1.0
10	.21	.29	.42	.63	.83	1.0	1.3
12	.25	.35	.50	.75	1.0	1.3	1.5
14	.29	.41	.58	.88	1.2	1.5	1.8
16	.33	.47	.67	1.0	1.3	1.7	2.0
20	.42	.58	.83	1.3	1.7	2.1	2.5
24	.50	.70	1.0	1.5	2.0	2.5	3.0
30	.63	.88	1.3	1.9	2.5	3.1	3.8

N.B.—This rule indicates that it makes no difference what is the diameter of pipe, provided it does not exceed twice the radius (R) of the sphere. No thicknesses are given for less test than 500 pounds because no lap-weld pipes are made that will not stand such test.

The strength of flat heads (Figs. 89, 98, and 101) is difficult to determine analytically, but the usually accepted formula is that of Grashof derived from the difficult "Theory of Elasticity." The formula is

$$T = \sqrt{\frac{5}{6} \times \frac{D^2}{4} \times \frac{p}{s}}.$$

If we use $pD = 2\,ts$ for cylindrical wall of pipe, we may combine the two rules, making p and s equal, and find that

$$T = 0.645\,\sqrt{tD}.$$

An approximate solution of this gives the thickness of head (in inches) here tabulated.

Table of Thickness of Flat Heads

External diameter of pipe	Thickness of pipe						
	C. J.*	.125	.20	.25	.375	.50	.75
2	.28	.32	.41	.46	.56	.64	....
4	.46	.46	.58	.64	.79	.91	1.1
6	.59	....	.71	.79	.97	1.1	1.4
8	.73	....	.82	.91	1.1	1.3	1.6
10	.85	....	.91	1.0	1.3	1.4	1.8
12	.98	....	1.0	1.1	1.4	1.6	1.9
16	1.3	....	....	1.3	1.6	1.8	2.2
20	1.5	....	....	....	1.8	2.0	2.5
24	1.8	....	....	....	1.9	2.2	2.7
30	2.3	....	....	....	....	2.5	3.1

* C. J. refers to the set of thicknesses given on page 43 for Converse joint pipe. For practical reasons it is not wise to attempt to weld less thickness of head in any diameter than given in this table. The great thickness of flat heads renders them advantageous for drilling and tapping connection holes.

SHELBY SEAMLESS STEEL SPECIALTIES

Shelby Seamless Steel Tubing is formed into special shapes to meet special requirements, where hollow forgings can be used to advantage to replace solid forgings requiring a boring operation, thus saving machine work and material. Special shapes made from seamless tubing have found a wide use, and new applications are constantly developing.

The homogeneous character of the material entering into a seamless tube permits the working of the material into a great variety of intricate shapes such as the requirements may demand.

By the cupping process, in which seamless articles are made by the progressive cupping of a round plate, certain special shapes may be produced without first producing the cylindrical tube.

Special shapes of tubular sections are usually formed hot, and are subject to certain variations of dimensions which are to be expected in all hot-forged articles.

The aim is to produce the forgings with just sufficient allowances to enable the user to finish them by machining to required dimensions where accurate sizes are required. In some cases, however, special shapes of uniform section are formed cold, in which case greater accuracy in formed dimensions is the rule.

Automobile Specialties

The illustrations cover a few automobile specialties, in the shape of axles. These axles are made from seamless tubing, of different material to suit the requirements.

These specialties are formed by swaging, expanding and upsetting either from hot-finished or cold-drawn tubing.

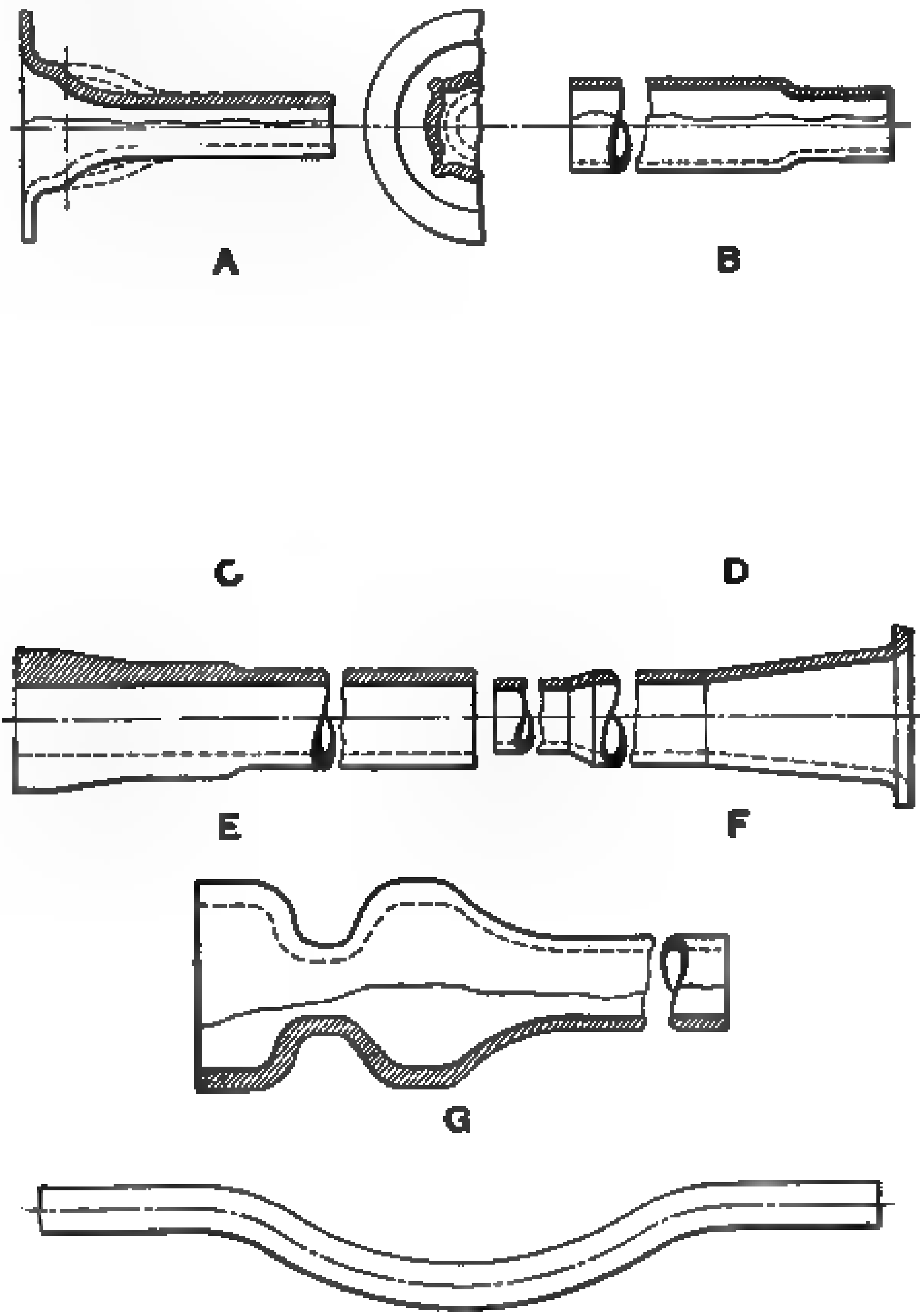


Fig. 104. Shelby Seamless Steel Front and Rear Axles

Cylinder Specialties

The illustrations below cover a few cylinder specialties, in the form of various styles of valve protecting caps, and also boiler shells and floats for feed water regulators, made partly direct by the cupping process, and partly from tubing.

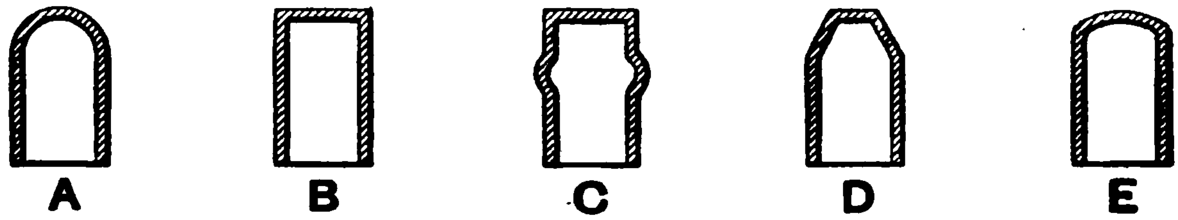


Fig. 105. Various Styles of Valve Protecting Cap Used on Carbonic Acid Gas Cylinders

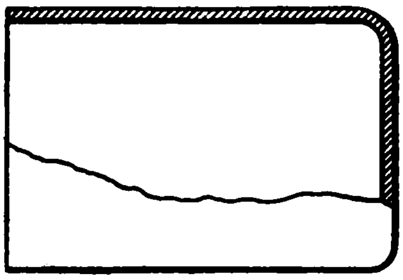


Fig. 106. Boiler Shells

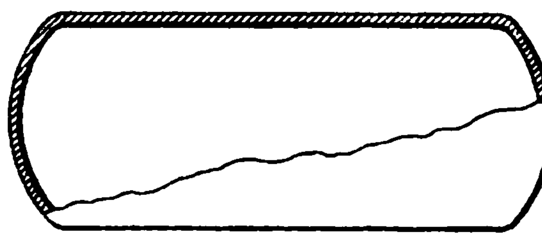


Fig. 107. Floats for Feed Water Regulators

Cream Separator Specialties

The illustrations below cover a few cream separator specialties made direct from plates.

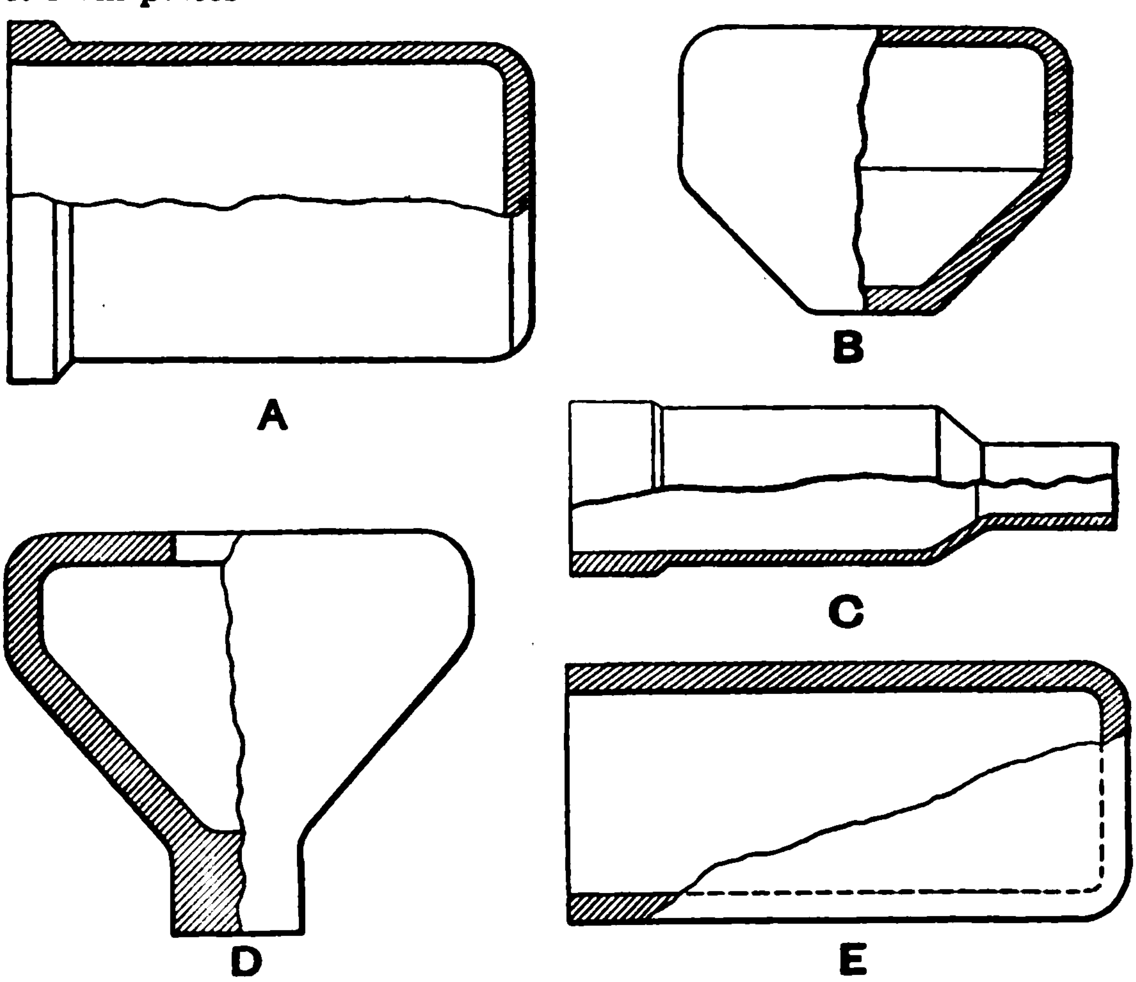


Fig. 108. Cream Separator Forgings

Bent Specialties

The illustrations below cover a few bent specialties.

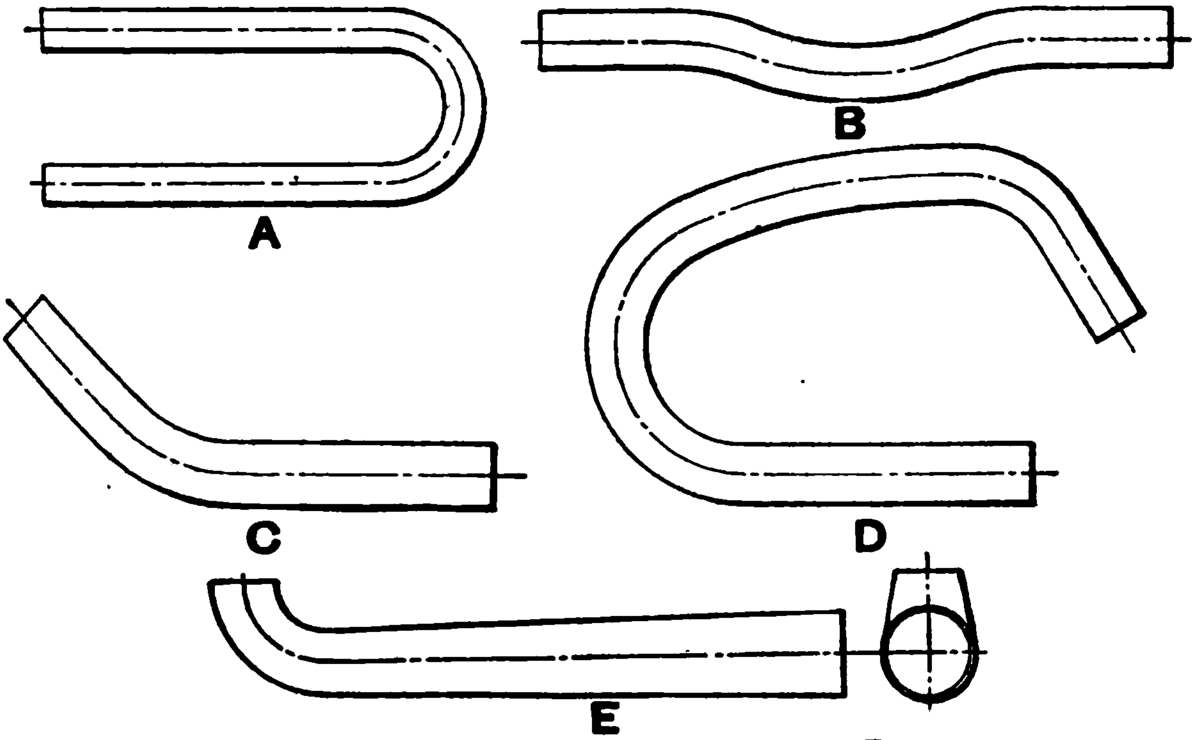


Fig. 109 Shelby Seamless Steel Tubes Bent

Miscellaneous Specialties

The illustrations below cover a few miscellaneous forgings, some of which are made direct from plates, and others from tubing.

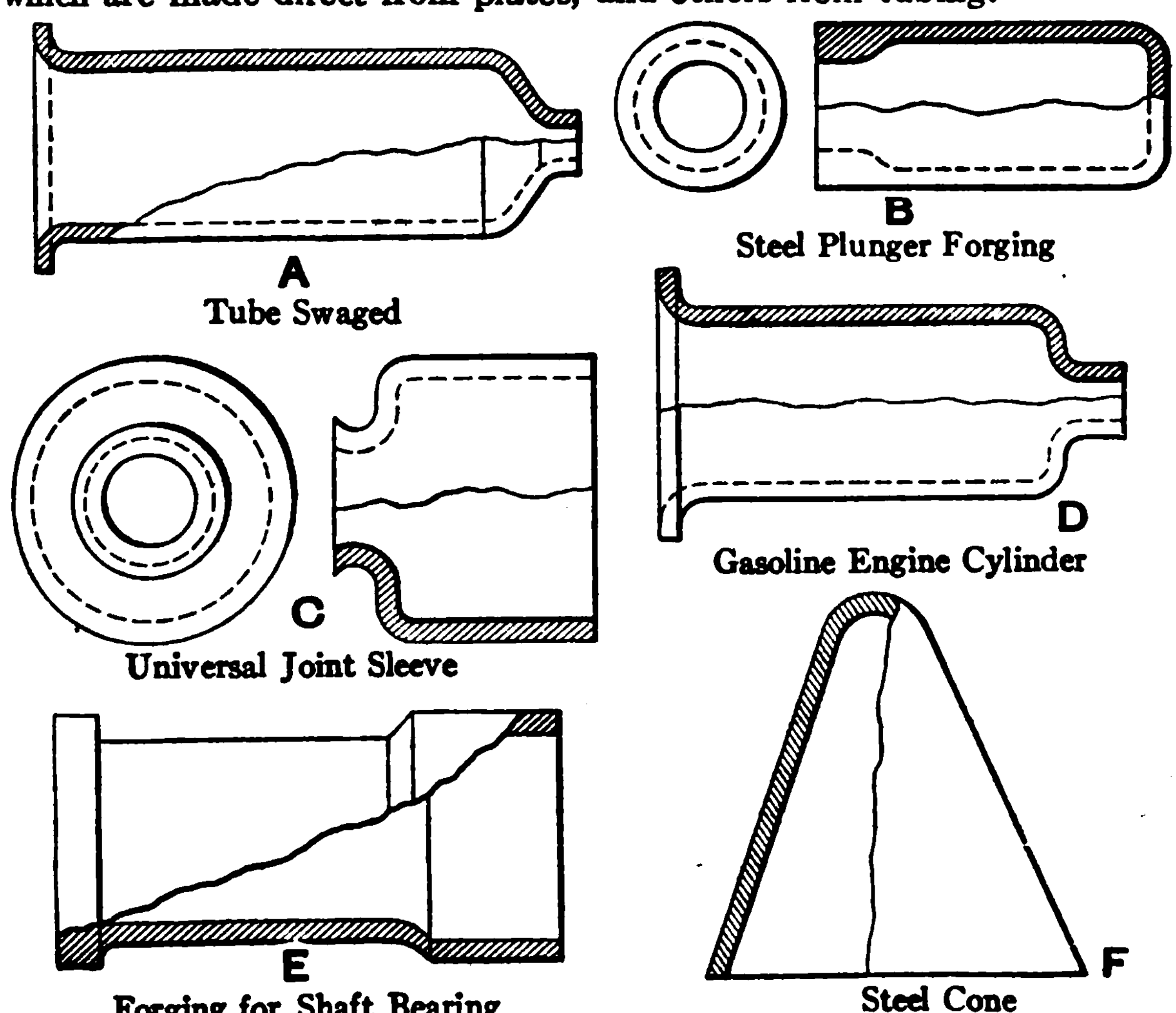
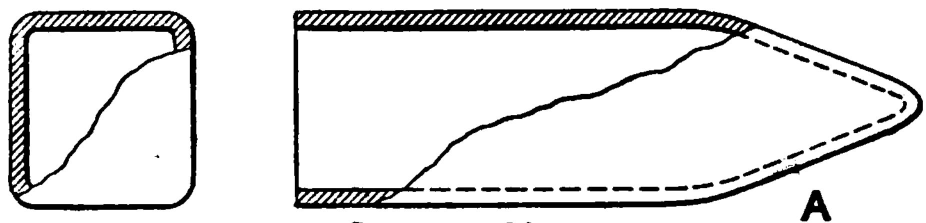


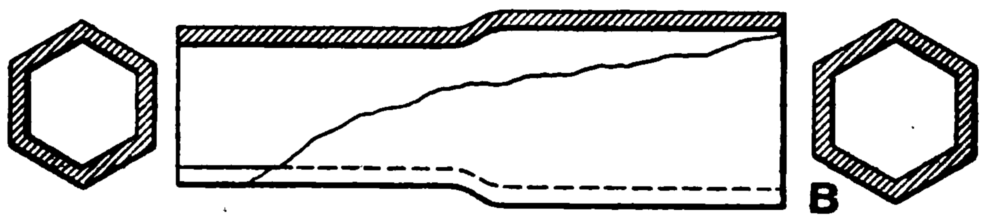
Fig. 110

Angular Section Specialties

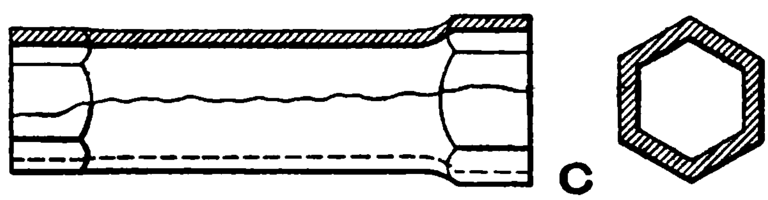
The illustrations below cover a few specialties in Angular section tubing, mainly in the shape of socket wrenches.



Square Tubing



Socket Wrench

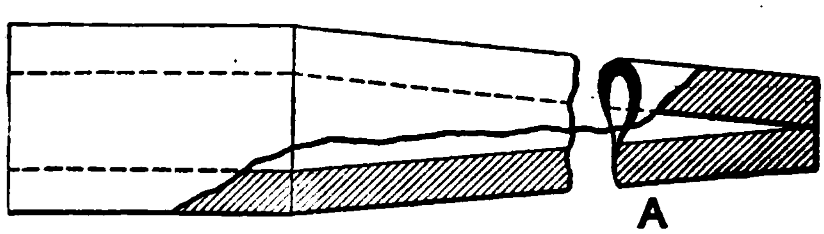


Socket Wrench

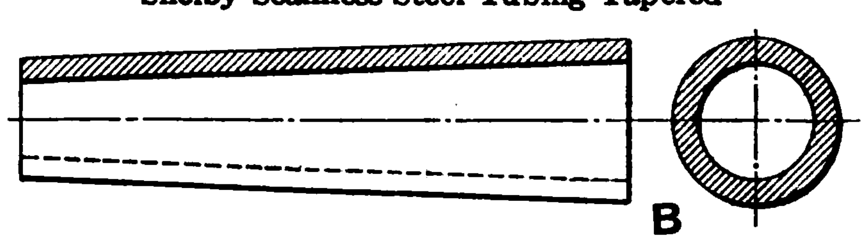
Fig. 111

Tapered Specialties

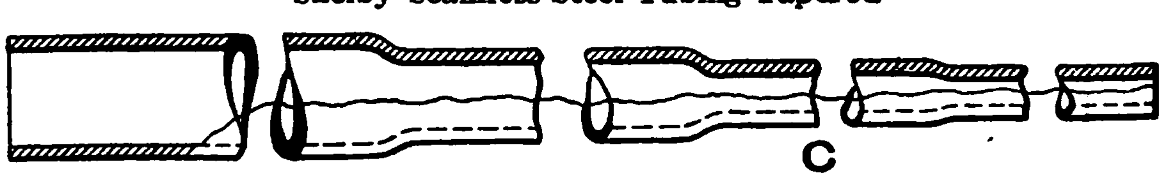
The illustrations below cover a few specialties of Taper Tubing. These tubes are tapered by different methods, as the conditions may call for.



Shelby Seamless Steel Tubing Tapered



Shelby Seamless Steel Tubing Tapered



Shelby Seamless Steel Tubing Tapered

Fig. 112

NOTE. We are prepared to furnish other specialties and will be glad to supply full information on receipt of blue prints or sketches showing exactly what is required.

SHELBY SEAMLESS COLD-DRAWN STEEL TROLLEY POLES

Under normal conditions of service, a trolley pole is subjected to stress as a beam rigidly secured at one end and loaded on the free end. This condition of loading causes a maximum bending moment at the point of support, which bending moment decreases uniformly to zero at the point of applying the load. Abnormal conditions cause other stresses of unknown magnitude, which can be provided against only by a judicious increase in the strength of the pole over that required for the known stresses.

The trolley pole of minimum weight, to resist the known stresses, would have a maximum cross-sectional area at the trolley base or point of support, with the cross section decreasing uniformly to nothing at the harp. For practical reasons, such a theoretical pole is not desirable. In the design of the Shelby poles, the theoretical requirement for minimum weight has received careful consideration, while providing for the unknown stresses and a practical form to suit the standard trolley bases and harps.

The standard Shelby poles are made from 13-gage material, as years of practical experience have shown that a lighter gage may fail by local injuries, and a heavier gage simply adds to the weight of the pole without increasing its strength to a corresponding extent. The theoretical requirement for a pole of minimum weight points out a method for increasing the strength of the pole without a proportionate increase in the weight. This method consists in the use of a reinforcement at the base end, and on the inside of the 13-gage member. The length of this reinforcement is varied, to suit the requirement as to strength, up to a maximum which occurs when the length of the reinforcement is such that the resistance to bending at the end of the reinforcement is just equal to the resistance to bending at the trolley base.

The Shelby trolley pole is regularly manufactured in two designs, viz.: Standard "A" and Standard "B."

In the Standard "A" pole, the reinforcement is only of sufficient length to prevent deformation of the circular section by the stresses caused by the service of the pole or by the clamp on the trolley base. This design is suitable for all ordinary service, and makes the lightest pole it is practicable to manufacture or use.

In the Standard "B" design, the reinforcement is of the maximum length required by the condition of two points in the length of the pole with equal resistance to bending. Speaking generally, the Standard "B" pole will be 20 per cent heavier and 50 per cent stronger than the Standard "A" pole. This design is intended to meet the most severe service conditions.

Externally, the two designs are duplicates, the outside diameter being 1½ inches, which, at a point 30 inches from the end of the pole, is reduced to 1⅜ inches, which diameter is again reduced to 1 inch for a distance of 6 inches from the end of the pole. The 1½-inch diameter

merges into the 1⅝-inch diameter, with fillets of large radii, and the 1⅝-inch diameter into the 1-inch diameter, with a gradual taper 6 inches long. The section 1 inch in diameter is reamed to a ¾-inch hole.

Special designs, varying in some or all particulars from the standard designs, are made to meet special requirements.

Shelby trolley poles are made from a selected grade of basic open-hearth steel of about 0.17 per cent carbon, low in phosphorus and sulphur. Prior to the last cold-drawing operation, the material is given a special heat treatment which leaves the grain in the finest condition. The elastic limit of the material in the finished pole is from 60 000 to 70 000 pounds per square inch.

Recent improvements have been made in the methods of manufacture, particularly in the method of inserting the reinforcement. As now made, the reinforcement is integral with the body of the pole, which adds materially to its efficiency.

The following table gives loads and deflections of various length poles at the elastic limit:

Length, feet	Average weight, pounds	Load carried at end of pole at elastic limit, pounds	Deflection due to load at elastic limit and weight of pole, inches
	Standard "A" Pole		
12	18.4	48	13¼
13	20.3	44	15¼
14	22.3	40	17¾
15	24.3	36	19½
	Standard "B" Pole		
12	22.7	75	22½
13	24.7	69	26½
14	26.7	62	30
15	28.7	55	33

PROPERTIES OF SHELBY SEAMLESS TUBING

Outside Diameter, Surface, and Volume or Displacement

Outside diameter. Inches	Outside surface per lineal foot		Lineal feet per square foot outside surface	External volume or displacement. Per lineal foot		
	Square inches	Square feet		Cubic inches	Cubic feet	United States gallons
½	18.85	.1309	7.639	2.356	.0014	.0102
⅝	23.56	.1636	6.112	3.682	.0021	.0159
¾	28.27	.1963	5.093	5.301	.0031	.0229
⅞	32.99	.2291	4.365	7.216	.0042	.0312
1	37.70	.2618	3.820	9.425	.0055	.0408
1⅛	42.41	.2945	3.395	11.93	.0069	.0516
1¼	47.12	.3272	3.056	14.73	.0085	.0637
1⅜	51.84	.3600	2.778	17.82	.0103	.0771
1½	56.55	.3927	2.546	21.21	.0123	.0918
1¾	65.97	.4581	2.183	28.86	.0167	.1249
2	75.40	.5236	1.910	37.70	.0218	.1632
2¼	84.82	.5890	1.698	47.71	.0276	.2065
2½	94.25	.6545	1.528	58.90	.0341	.2550
2¾	103.67	.7199	1.389	71.27	.0412	.3085
3	113.10	.7854	1.273	84.82	.0491	.3672
3¼	122.52	.8508	1.175	99.55	.0576	.4309
3½	131.95	.9163	1.091	115.45	.0668	.4998
3¾	141.37	.9817	1.019	132.54	.0767	.5737
4	150.80	1.0472	.955	150.80	.0873	.6528
4¼	160.22	1.1126	.899	170.24	.0985	.7369
4½	169.65	1.1781	.849	190.85	.1104	.8262
4¾	179.07	1.2435	.804	212.65	.1231	.9205
5	188.50	1.3090	.764	235.62	.1364	1.0200
5¼	197.91	1.3744	.728	259.77	.1503	1.1245
5½	207.35	1.4399	.694	285.10	.1650	1.2342
5¾	216.76	1.5053	.664	311.61	.1803	1.3489
6	226.20	1.5708	.637	339.29	.1963	1.4688

Sectional Area of Wall in Square Inches

Outside diam. Inches	Thickness in gage and fractions of an inch							
	22 B.W.G.	20 B.W.G.	18 B.W.G.	1/16	3/32	1/8	5/32	3/16
½	.04152	.05113	.06943	.0859	.1197	.1473		
⅝	.05251	.06487	.08867	.1104	.1565	.1963		
¾	.06351	.07862	.1079	.1350	.1933	.2454	.2915	.3313
⅞	.07451	.09236	.1272	.1595	.2301	.2945	.3528	.4050
1	.08550	.1061	.1464	.1841	.2669	.3436	.4142	.4786
1⅛	.09650	.1199	.1656	.2086	.3037	.3927	.4755	.5522
1¼	.1075	.1336	.1849	.2332	.3405	.4418	.5369	.6259
1⅜	...	.1473	.2041	.2577	.3774	.4909	.5983	.6995
1½	...	.1611	.2234	.2823	.4142	.5400	.6596	.7731
1¾	...	...	...	.3313	.4878	.6381	.7823	.9204
2	...	...	...	.3804	.5614	.7363	.9050	1.068
2¼	...	...	...	.4295	.6351	.8345	1.028	1.215
2½	...	...	...	.4786	.7087	.9327	1.150	1.362
2¾	...	...	...	.5277	.7823	1.031	1.273	1.509
3	...	...	...	...	.8560	1.129	1.396	1.657
3¼	...	...	...	...	.9296	1.227	1.519	1.804
3½	...	...	...	...	1.003	1.325	1.641	1.951
3¾	...	...	...	...	...	1.424	1.764	2.098
4	...	...	...	...	...	1.522	1.887	2.246
4¼	...	...	...	...	...	...	2.010	2.393
4½	...	...	...	...	...	...	2.132	2.540
4¾	...	...	...	...	...	...	2.255	2.688
5	...	...	...	...	...	...	2.378	2.835
5¼	...	...	...	...	...	...	2.501	2.983
5½	...	...	...	...	...	...	2.623	3.129
5¾	...	...	...	...	...	...	2.746	3.277
6	...	...	...	...	...	...	2.868	3.424

Capacity in Cubic Inches per Lineal Foot

Outside diam. Inches	22 B.W.G.	20 B.W.G.	18 B.W.G.	1/16	3/32	1/8	5/32	3/16
½	1.858	1.743	1.523	1.325	.920	.589		
⅝	3.051	2.903	2.618	2.356	1.804	1.325		
¾	4.539	4.358	4.007	3.682	2.982	2.356	1.804	1.325
⅞	6.322	6.107	5.690	5.301	4.455	3.682	2.982	2.356
1	8.399	8.151	7.668	7.216	6.222	5.301	4.455	3.682
1⅛	10.770	10.490	9.941	9.425	8.283	7.216	6.222	5.301
1¼	13.436	13.123	12.508	11.93	10.64	9.425	8.283	7.216
1⅜	...	16.051	15.37	14.73	13.29	11.93	10.64	9.425
1½	...	19.273	18.53	17.82	16.24	14.73	13.29	11.93
1¾	...	...	...	24.89	23.01	21.21	19.48	17.82
2	...	...	...	33.13	30.96	28.86	26.84	24.89
2¼	...	...	...	42.56	40.09	37.70	35.38	33.13
2½	...	...	...	53.16	50.40	47.71	45.10	42.56
2¾	...	...	...	64.94	61.89	58.90	56.00	53.16
3	...	...	...	...	74.55	71.27	68.07	64.94
3¼	...	...	...	...	88.39	84.82	81.33	77.90
3½	...	...	...	...	103.41	99.55	95.76	92.04
3¾	...	...	...	...	...	115.45	111.37	107.35
4	...	...	...	...	...	132.54	128.15	123.85
4¼	...	...	...	...	...	...	146.12	141.52
4½	...	...	...	...	...	...	165.26	160.37
4¾	...	...	...	...	...	...	185.59	180.40
5	...	...	...	...	...	...	207.09	201.60
5¼	...	...	...	...	...	...	229.76	223.99
5½	...	...	...	...	...	...	253.62	247.55
5¾	...	...	...	...	...	...	278.65	272.28
6	...	...	...	...	...	...	304.87	298.20

Sectional Area of Wall in Square Inches

Outside diam. Inches	Thickness in fractions of an inch								
	7/32	1/4	5/16	3/8	1/2	5/8	3/4	7/8	1
1/2									
5/8									
3/4									
7/8	.4510								
1	.5369	.5890							
1 1/8	.6228	.6872							
1 1/4	.7087	.7854	.9204	1.031					
1 3/8	.7946	.8836	1.043	1.178					
1 1/2	.8805	.9817	1.166	1.325	1.571				
1 3/4	1.052	1.178	1.411	1.620	1.963				
2	1.224	1.374	1.657	1.914	2.356	2.700			
2 1/4	1.396	1.571	1.902	2.209	2.749	3.191			
2 1/2	1.568	1.767	2.148	2.503	3.142	3.682			
2 3/4	1.740	1.963	2.393	2.798	3.534	4.172			
3	1.911	2.160	2.638	3.093	3.927	4.663	5.301	5.841	6.283
3 1/4	2.083	2.356	2.884	3.387	4.320	5.154	5.890	6.529	7.069
3 1/2	2.255	2.553	3.129	3.682	4.712	5.645	6.480	7.216	7.854
3 3/4	2.427	2.749	3.375	3.976	5.105	6.136	7.069	7.903	8.639
4	2.599	2.945	3.620	4.271	5.498	6.627	7.658	8.590	9.425
4 1/4	2.770	3.142	3.866	4.565	5.890	7.118	8.247	9.278	10.210
4 1/2	2.942	3.338	4.111	4.860	6.283	7.609	8.836	9 965	10.996
4 3/4	3.114	3.534	4.357	5.154	6.676	8.099	9.425	10.652	11.781
5	3.286	3.731	4.602	5.449	7.069	8.590	10.014	11.339	12.566
5 1/4	3.458	3.927	4.848	5.744	7.462	9.082	10.603	12.029	13.352
5 1/2	3.629	4.123	5.093	6.038	7.854	9.572	11.192	12.714	14.137
5 3/4	3.801	4.320	5.338	6.332	8.246	10.063	11.781	13.401	14.922
6	3.973	4.516	5.583	6.626	8.639	10.553	12.370	14.088	15.708

Capacity in Cubic Inches per Lineal Foot

1/2									
5/8									
3/4									
7/8	1.804								
1	2.982	2.356							
1 1/8	4.455	3.682							
1 1/4	6.222	5.301	3.682	2.356					
1 3/8	8.283	7.216	5.301	3.682					
1 1/2	10.64	9.425	7.216	5.301	2.356				
1 3/4	16.24	14.73	11.93	9.425	5.301				
2	23.01	21.21	17.82	14.73	9.425	5.301			
2 1/4	30.96	28.86	24.89	21.21	14.73	9.425			
2 1/2	40.09	37.70	33.13	28.86	21.21	14.73			
2 3/4	50.40	47.71	42.56	37.70	28.86	21.21			
3	61.89	58.90	53.16	47.71	37.70	28.86	21.21	14.73	9.425
3 1/4	74.55	71.27	64.94	58.90	47.71	37.70	28.86	21.21	14.73
3 1/2	88.39	84.82	77.90	71.27	58.90	47.71	37.70	28.86	21.21
3 3/4	103.41	99.55	92.04	84.82	71.27	58.90	47.71	37.70	28.86
4	119.61	115.45	107.35	99.55	84.82	71.27	58.90	47.71	37.70
4 1/4	136.99	132.54	123.85	115.45	99.55	84.82	71.27	58.90	47.71
4 1/2	155.55	150.80	141.52	132.54	115.45	99.55	84.82	71.27	58.90
4 3/4	175.28	170.24	160.37	150.80	132.54	115.45	99.55	84.82	71.27
5	196.19	190.85	180.40	170.24	150.80	132.54	115.45	99.55	84.82
5 1/4	218.28	212.65	201.60	190.85	170.24	150.80	132.54	115.45	99.55
5 1/2	241.55	235.62	223.99	212.65	190.85	170.24	150.80	132.54	115.45
5 3/4	265.99	259.78	247.55	235.62	212.65	190.85	170.24	150.80	132.54
6	291.61	285.10	272.28	259.78	235.62	212.65	190.85	170.24	150.80

Capacity in Cubic Feet per Lineal Foot

Outside diam. Inches	Thickness in gage and fractions of an inch							
	22 B.W.G.	20 B.W.G.	18 B.W.G.	1/16	3/32	1/8	5/32	3/16
1/2	.00108	.00101	.00088	.00077	.00053	.00034		
5/8	.00177	.00168	.00151	.00136	.00104	.00077		
3/4	.00263	.00252	.00232	.00213	.00173	.00136	.00104	.00077
7/8	.00366	.00353	.00329	.00307	.00258	.00213	.00173	.00136
1	.00486	.00472	.00444	.00418	.00360	.00307	.00258	.00213
1 1/8	.00623	.00607	.00575	.00545	.00479	.00418	.00360	.00307
1 1/4	.00778	.00759	.00724	.00690	.00616	.00545	.00479	.00418
1 3/8		.00929	.00889	.00852	.00769	.00690	.00616	.00545
1 1/2		.01115	.01072	.01031	.00940	.00852	.00769	.00690
1 3/4				.01440	.01332	.01227	.01127	.01031
2				.01917	.01792	.01670	.01553	.01440
2 1/4				.02463	.02320	.02182	.02047	.01917
2 1/2				.03076	.02917	.02761	.02610	.02463
2 3/4				.03758	.03581	.03409	.03241	.03076
3					.04314	.04125	.03939	.03758
3 1/4					.05115	.04909	.04706	.04508
3 1/2					.05985	.05761	.05542	.05326
3 3/4						.06681	.06445	.06213
4						.07670	.07416	.07167
4 1/4							.08456	.08190
4 1/2							.09564	.09281
4 3/4							.10740	.10440
5							.11984	.11667
5 1/4							.13297	.12962
5 1/2							.14677	.14326
5 3/4							.16126	.15757
6							.17643	.17257

Capacity in U. S. Gallons per Lineal Foot

1/2	.0080	.0075	.0066	.0057	.0040	.0025		
5/8	.0132	.0126	.0113	.0102	.0078	.0057		
3/4	.0197	.0189	.0173	.0159	.0129	.0102	.0078	.0057
7/8	.0274	.0264	.0246	.0229	.0193	.0159	.0129	.0102
1	.0364	.0353	.0332	.0312	.0269	.0229	.0193	.0159
1 1/8	.0467	.0454	.0430	.0408	.0359	.0312	.0269	.0229
1 1/4	.0582	.0568	.0541	.0516	.0461	.0408	.0359	.0312
1 3/8		.0695	.0665	.0637	.0575	.0516	.0461	.0408
1 1/2		.0834	.0802	.0771	.0703	.0637	.0575	.0516
1 3/4				.1077	.0996	.0918	.0843	.0771
2				.1434	.1340	.1249	.1162	.1077
2 1/4				.1842	.1736	.1632	.1532	.1434
2 1/2				.2301	.2182	.2065	.1952	.1842
2 3/4				.2811	.2679	.2550	.2424	.2301
3					.3227	.3085	.2947	.2811
3 1/4					.3827	.3672	.3521	.3372
3 1/2					.4477	.4309	.4145	.3984
3 3/4						.4998	.4821	.4647
4						.5737	.5548	.5361
4 1/4							.6326	.6126
4 1/2							.7154	.6942
4 3/4							.8034	.7809
5							.8965	.8727
5 1/4							.9946	.9696
5 1/2							1.0979	1.0716
5 3/4							1.2063	1.1787
6							1.3198	1.2909

Capacity in Cubic Feet per Lineal Foot

Outside diam. Inches	Thickness in fractions of an inch								
	7/32	1/4	5/16	3/8	1/2	5/8	3/4	7/8	1
1/2									
5/8									
3/4									
7/8	.00104								
1	.00173	.00136							
1 1/8	.00258	.00213							
1 1/4	.00360	.00307	.00213	.00136					
1 3/8	.00479	.00418	.00307	.00213					
1 1/2	.00616	.00545	.00418	.00307	.00136				
1 3/4	.00940	.00852	.00690	.00545	.00307				
2	.01332	.01227	.01031	.00852	.00545	.00307			
2 1/4	.01792	.01670	.01440	.01227	00852	.00545			
2 1/2	.02320	.02182	.01917	.01670	.01227	.00852			
2 3/4	.02917	.02761	.02463	.02182	.01670	.01227			
3	.03581	.03409	.03076	.02761	.02182	.01670	.01227	.00852	.00545
3 1/4	.04314	.04125	.03758	.03409	.02761	.02182	.01670	.01227	.00852
3 1/2	.05115	.04909	.04508	.04125	.03409	.02761	.02182	.01670	.01227
3 3/4	.05985	.05761	.05326	.04909	.04125	.03409	.02761	.02182	.01670
4	.06922	.06681	.06213	.05761	.04909	.04125	.03409	.02761	.02182
4 1/4	.07928	.07670	.07167	.06681	.05761	.04909	.04125	.03409	.02761
4 1/2	.09002	.08727	.08190	.07670	.06681	.05761	.04909	.04125	.03409
4 3/4	.10143	.09852	.09281	.08727	.07670	.06681	.05761	.04909	.04125
5	.11354	.11045	.10440	.09852	.08727	.07670	.06681	.05761	.04909
5 1/4	.12632	.12306	.11667	.11045	.09852	.08727	.07670	.06681	.05761
5 1/2	.13978	.13635	.12962	.12306	.11045	.09852	.08727	.07670	.06681
5 3/4	.15393	.15033	.14326	.13635	.12306	.11045	.09852	.08727	.07670
6	.16876	.16499	.15757	.15033	.13635	.12306	.11045	.09852	.08727

Capacity in U. S. Gallons per Lineal Foot

Outside diam. Inches	7/32	1/4	5/16	3/8	1/2	5/8	3/4	7/8	1
1/2									
5/8									
3/4									
7/8	.0078								
1	.0129	.0102							
1 1/8	.0193	.0159							
1 1/4	.0269	.0229	.0159	.0102					
1 3/8	.0359	.0312	.0229	.0159					
1 1/2	.0461	.0408	.0312	.0229	.0102				
1 3/4	.0703	.0637	.0516	.0408	.0229				
2	.0996	.0918	.0771	.0637	.0408	.0229			
2 1/4	.1340	.1249	.1077	.0918	.0637	.0408			
2 1/2	.1736	.1632	.1434	.1249	.0918	.0637			
2 3/4	.2182	.2065	.1842	.1632	.1249	.0918			
3	.2679	.2550	.2301	.2065	.1632	.1249	.0918	.0637	.0408
3 1/4	.3227	.3085	.2811	.2550	.2065	.1632	.1249	.0918	.0637
3 1/2	.3827	.3672	.3372	.3085	.2550	.2065	.1632	.1249	.0918
3 3/4	.4477	.4309	.3984	.3672	.3085	.2550	.2065	.1632	.1249
4	.5178	.4998	.4647	.4309	.3672	.3085	.2550	.2065	.1632
4 1/4	.5930	.5737	.5361	.4998	.4309	.3672	.3085	.2550	.2065
4 1/2	.6734	.6528	.6126	.5737	.4998	.4309	.3672	.3085	.2550
4 3/4	.7588	.7369	.6942	.6528	.5737	.4998	.4309	.3672	.3085
5	.8493	.8262	.7809	.7369	.6528	.5737	.4998	.4309	.3672
5 1/4	.9449	.9205	.8727	.8262	.7369	.6528	.5737	.4998	.4309
5 1/2	1.0457	1.0200	.9696	.9205	.8262	.7369	.6528	.5737	.4998
5 3/4	1.1515	1.1246	1.0716	1.0200	.9205	.8262	.7369	.6528	.5737
6	1.2624	1.2342	1.1787	1.1246	1.0200	.9205	.8262	.7369	.6528

Moment of Inertia, I, for Neutral Axis through Center of Section

Outside diam. Inches	Thickness in gage and fractions of an inch.							
	22 B.W.G.	20 B.W.G.	18 B.W.G.	1/16	3/32	1/8	5/32	3/16
1/2	.00116	.00139	.00179	.00210	.00260	.00288		
5/8	.00234	.00283	.00370	.00442	.00569	.00652		
3/4	.00414	.00504	.00666	.00804	.01062	.01246	.01373	.01456
7/8	.00669	.00816	.01088	.01324	.01781	.02128	.02386	.02571
1	.01011	.01237	.01659	.02031	.02769	.03356	.03812	.04160
1 1/8	.01453	.01782	.02402	.02954	.04071	.04985	.05724	.06310
1 1/4	.02008	.02467	.03339	.04121	.05728	.07075	.08192	.09107
1 3/8	....	.03309	.04493	.05562	.07785	.09683	.1129	.1264
1 1/2	....	.04324	.05885	.07304	.1028	.1287	.1509	.1699
1 3/4	....	....	....	.1181	.1678	.2119	.2508	.2849
2	....	....	....	.1787	.2556	.3250	.3873	.4431
2 1/4	....	....	....	.2571	.3698	.4727	.5663	.6514
2 1/2	....	....	....	.3557	.5137	.6594	.7935	.9165
2 3/4	....	....	....	.4767	.6909	.8899	1.075	1.246
3	....	....	....	....	.9047	1.169	1.415	1.645
3 1/4	....	....	....	....	1.159	1.500	1.822	2.123
3 1/2	....	....	....	....	1.456	1.890	2.299	2.685
3 3/4	....	....	....	....	....	2.341	2.853	3.338
4	....	....	....	....	....	2.859	3.490	4.092
4 1/4	....	....	....	....	....	....	4.216	4.947
4 1/2	....	....	....	....	....	....	5.035	5.917
4 3/4	....	....	....	....	....	....	5.955	7.005
5	....	....	....	....	....	....	6.980	8.219
5 1/4	....	....	....	....	....	....	8.117	9.566
5 1/2	....	....	....	....	....	....	9.371	11.05
5 3/4	....	....	....	....	....	....	10.75	12.69
6	....	....	....	....	....	....	12.26	14.48

Section Modulus, Z, for Neutral Axis through Center of Section

Outside diam. Inches	22 B.W.G.	20 B.W.G.	18 B.W.G.	1/16	3/32	1/8	5/32	3/16
1/2	.00461	.00556	.00714	.00839	.01040	.0115		
5/8	.00750	.00906	.0119	.0142	.0182	.0209		
3/4	.0111	.0134	.0178	.0214	.0283	.0332	.0366	.0388
7/8	.0153	.0187	.0249	.0303	.0407	.0486	.0545	.0588
1	.0202	.0247	.0332	.0406	.0554	.0671	.0762	.0832
1 1/8	.0258	.0317	.0427	.0525	.0724	.0886	.1018	.1122
1 1/4	.0321	.0395	.0534	.0659	.0917	.1132	.1311	.1457
1 3/8	....	.0481	.0653	.0809	.1132	.1408	.1642	.1838
1 1/2	....	.0577	.0785	.0974	.1371	.1716	.2012	.2265
1 3/4	....	....	....	.1350	.1918	.2422	.2866	.3256
2	....	....	....	.1787	.2556	.3250	.3873	.4431
2 1/4	....	....	....	.2286	.3287	.4201	.5034	.5790
2 1/2	....	....	....	.2845	.4110	.5275	.6348	.7332
2 3/4	....	....	....	.3467	.5024	.6472	.7815	.9059
3	....	....	....	....	.6031	.7791	.9436	1.097
3 1/4	....	....	....	....	.7130	.9233	1.121	1.306
3 1/2	....	....	....	....	.8321	1.080	1.314	1.534
3 3/4	....	....	....	....	....	1.249	1.522	1.780
4	....	....	....	....	....	1.430	1.745	2.046
4 1/4	....	....	....	....	....	....	1.984	2.328
4 1/2	....	....	....	....	....	....	2.238	2.630
4 3/4	....	....	....	....	....	....	2.507	2.949
5	....	....	....	....	....	....	2.792	3.288
5 1/4	....	....	....	....	....	....	3.092	3.644
5 1/2	....	....	....	....	....	....	3.408	4.019
5 3/4	....	....	....	....	....	....	3.738	4 413
6	....	....	....	....	....	....	4.085	4.825

Moment of Inertia, I, for Neutral Axis through Center of Section

Outside diam. Inches	Thickness in fractions of an inch								
	7/32	1/4	5/16	3/8	1/2	5/8	3/4	7/8	1
1/2									
5/8									
3/4									
7/8	.02698								
1	.04417	.04602							
1 1/8	.06766	.07114							
1 1/4	.09845	.1043	.1124	.1168					
1 3/8	.1375	.1467	.1599	.1680					
1 1/2	.1859	.1994	.2197	.2330	.2454				
1 3/4	.3147	.3405	.3818	.4113	.4449				
2	.4928	.5369	.6099	.6656	.7363	.7699			
2 1/4	.7283	.7978	.9158	1.010	1.138	1.209			
2 1/2	1.029	1.132	1.311	1.457	1.669	1.798			
2 3/4	1.404	1.549	1.806	2.022	2.347	2.559			
3	1.860	2.059	2.414	2.718	3.191	3.516	3.728	3.856	3.927
3 1/4	2.405	2.669	3.146	3.559	4.218	4.691	5.016	5.228	5.357
3 1/2	3.048	3.390	4.013	4.559	5.449	6.108	6.581	6.906	7.118
3 3/4	3.797	4.231	5.026	5.731	6.900	7.790	8.449	8.922	9.247
4	4.660	5.200	6.197	7.090	8.590	9.759	10.65	11.31	11.78
4 1/4	5.644	6.308	7.539	8.649	10.54	12.04	13.21	14.10	14.76
4 1/2	6.759	7.563	9.061	10.42	12.76	14.65	16.15	17.32	18.21
4 3/4	8.011	8.974	10.78	12.42	15.28	17.62	19.51	21.01	22.18
5	9.409	10.55	12.70	14.66	18.11	20.97	23.31	25.20	26.70
5 1/4	10.96	12.30	14.83	17.16	21.27	24.72	27.58	29.92	31.81
5 1/2	12.68	14.24	17.19	19.93	24.79	28.90	32.35	35.21	37.55
5 3/4	14.56	16.37	19.79	22.98	28.67	33.53	37.64	41.09	43.95
6	16.63	18.70	22.65	26.33	32.94	38.63	43.49	47.60	51.05

Section Modulus, Z, for Neutral Axis through Center of Section

1/2									
5/8									
3/4									
7/8	.0617								
1	.0883	.0920							
1 1/8	.1203	.1265							
1 1/4	.1575	.1669	.1798	.1869					
1 3/8	.2001	.2134	.2326	.2443					
1 1/2	.2479	.2659	.2930	.3106	.3272				
1 3/4	.3597	.3892	.4363	.4701	.5084				
2	.4928	.5369	.6099	.6656	.7363	.7699			
2 1/4	.6474	.7090	.8140	.8974	1.012	1.075			
2 1/2	.8234	.9057	1.049	1.166	1.335	1.438			
2 3/4	1.021	1.127	1.314	1.471	1.707	1.861			
3	1.240	1.372	1.610	1.812	2.127	2.344	2.485	2.571	2.618
3 1/4	1.480	1.643	1.936	2.190	2.596	2.887	3.087	3.217	3.295
3 1/2	1.742	1.937	2.293	2.605	3.114	3.490	3.760	3.946	4.067
3 3/4	2.025	2.256	2.680	3.057	3.680	4.155	4.506	4.758	4.932
4	2.330	2.600	3.099	3.545	4.295	4.880	5.324	5.654	5.891
4 1/4	2.656	2.968	3.548	4.070	4.959	5.665	6.215	6.634	6.944
4 1/2	3.004	3.361	4.027	4.632	5.672	6.512	7.179	7.698	8.094
4 3/4	3.373	3.778	4.537	5.230	6.434	7.420	8.216	8.847	9.340
5	3.764	4.220	5.078	5.866	7.245	8.389	9.325	10.081	10.681
5 1/4	4.176	4.687	5.650	6.538	8.105	9.419	10.508	11.400	12.120
5 1/2	4.609	5.178	6.252	7.247	9.014	10.510	11.764	12.804	13.655
5 3/4	5.064	5.693	6.885	7.993	9.972	11.663	13.094	14.293	15.288
6	5.541	6.233	7.549	8.775	10.979	12.876	14.496	15.867	17.017

Radius of Gyration, R, for Neutral Axis through Center of Section

Outside diam. Inches	Thickness in gage and fractions of an inch							
	22 B.W.G.	20 B.W.G.	18 B.W.G.	1/16	3/32	1/8	5/32	3/16
1/2	.1672	.1649	.1604	.1563	.1474	.1398		
5/8	.2113	.2090	.2044	.2001	.1907	.1822		
3/4	.2555	.2531	.2484	.2441	.2344	.2253	.2171	.2096
7/8	.2996	.2972	.2925	.2881	.2782	.2688	.2601	.2519
1	.3438	.3414	.3367	.3322	.3221	.3125	.3034	.2948
1 1/8	.3880	.3856	.3808	.3763	.3661	.3563	.3469	.3380
1 1/4	.4322	.4297	.4250	.4204	.4101	.4002	.3906	.3815
1 3/8	....	.4739	.4691	.4646	.4542	.4441	.4344	.4250
1 1/2	....	.5181	.5133	.5087	.4983	.4881	.4783	.4688
1 3/4	....	....	....	.5970	.5865	.5762	.5662	.5564
2	....	....	....	.6854	.6748	.6644	.6542	.6442
2 1/4	....	....	....	.7737	.7631	.7526	.7423	.7322
2 1/2	....	....	....	.8621	.8513	.8409	.8305	.8203
2 3/4	....	....	....	.9504	.9397	.9291	.9187	.9084
3	....	....	....	....	1.028	1.017	1.007	.9966
3 1/4	....	....	....	....	1.116	1.106	1.095	1.085
3 1/2	....	....	....	....	1.205	1.194	1.183	1.173
3 3/4	....	....	....	....	....	1.282	1.272	1.261
4	....	....	....	....	....	1.371	1.360	1.350
4 1/4	....	....	....	....	....	....	1.448	1.438
4 1/2	....	....	....	....	....	....	1.537	1.526
4 3/4	....	....	....	....	....	....	1.625	1.614
5	....	....	....	....	....	....	1.713	1.703
5 1/4	....	....	....	....	....	....	1.802	1.791
5 1/2	....	....	....	....	....	....	1.890	1.879
5 3/4	....	....	....	....	....	....	1.979	1.968
6	....	....	....	....	....	....	2.067	2.056

Inside Surface in Square Feet per Lineal Foot

1/2	.1162	.1126	.1052	.0982	.0818	.0654		
5/8	.1490	.1453	.1380	.1309	.1145	.0982		
3/4	.1817	.1780	.1707	.1636	.1473	.1309	.1145	.0982
7/8	.2144	.2107	.2034	.1963	.1800	.1636	.1473	.1309
1	.2471	.2435	.2361	.2291	.2127	.1963	.1800	.1636
1 1/8	.2799	.2762	.2689	.2618	.2454	.2291	.2127	.1963
1 1/4	.3126	.3089	.3016	.2945	.2782	.2618	.2454	.2291
1 3/8	....	.3416	.3343	.3272	.3109	.2945	.2782	.2618
1 1/2	....	.3744	.3670	.3600	.3436	.3272	.3109	.2945
1 3/4	....	....	....	.4254	.4091	.3927	.3763	.3600
2	....	....	....	.4909	.4745	.4581	.4418	.4254
2 1/4	....	....	....	.5563	.5400	.5236	.5072	.4909
2 1/2	....	....	....	.6218	.6054	.5890	.5727	.5563
2 3/4	....	....	....	.6872	.6709	.6545	.6381	.6218
3	....	....	....	....	.7363	.7199	.7036	.6872
3 1/4	....	....	....	....	.8018	.7854	.7690	.7527
3 1/2	....	....	....	....	.8672	.8508	.8345	.8181
3 3/4	....	....	....	....	....	.9163	.8999	.8836
4	....	....	....	....	....	.9817	.9654	.9490
4 1/4	....	....	....	....	....	....	1.0308	1.0145
4 1/2	....	....	....	....	....	....	1.0963	1.0799
4 3/4	....	....	....	....	....	....	1.1617	1.1454
5	....	....	....	....	....	....	1.2272	1.2108
5 1/4	....	....	....	....	....	....	1.2926	1.2763
5 1/2	....	....	....	....	....	....	1.3581	1.3417
5 3/4	....	....	....	....	....	....	1.4235	1.4072
6	....	....	....	....	....	....	1.4890	1.4726

Radius of Gyration, R, for Neutral Axis through Center of Section

Outside diam. Inches	Thickness in fractions of an inch								
	7/32	1/4	5/16	3/8	1/2	5/8	3/4	7/8	1
1/2									
5/8									
3/4									
7/8	.2446								
1	.2868	.2795							
1 1/8	.3296	.3217							
1 1/4	.3727	.3644	.3494	.3366					
1 3/8	.4160	.4075	.3916	.3776					
1 1/2	.4595	.4507	.4341	.4193	.3953				
1 3/4	.5469	.5376	.5201	.5039	.4760				
2	.6345	.6250	.6068	.5896	.5590	.5340			
2 1/4	.7223	.7126	.6939	.6760	.6435	.6156			
2 1/2	.8102	.8004	.7813	.7629	.7289	.6988			
2 3/4	.8983	.8883	.8688	.8501	.8149	.7831			
3	.9864	.9763	.9566	.9375	.9014	.8683	.8385	.8125	.7906
3 1/4	1.074	1.064	1.044	1.025	.9882	.9540	.9228	.8949	.8705
3 1/2	1.163	1.152	1.132	1.113	1.075	1.040	1.008	.9783	.9520
3 3/4	1.251	1.241	1.220	1.201	1.163	1.127	1.093	1.063	1.035
4	1.339	1.329	1.308	1.288	1.250	1.214	1.179	1.147	1.118
4 1/4	1.427	1.417	1.396	1.376	1.338	1.301	1.266	1.233	1.202
4 1/2	1.516	1.505	1.485	1.464	1.425	1.388	1.352	1.318	1.287
4 3/4	1.604	1.593	1.573	1.552	1.513	1.475	1.439	1.405	1.372
5	1.692	1.682	1.661	1.641	1.601	1.563	1.526	1.491	1.458
5 1/4	1.780	1.770	1.749	1.729	1.689	1.650	1.613	1.577	1.544
5 1/2	1.869	1.858	1.837	1.817	1.777	1.738	1.700	1.664	1.630
5 3/4	1.957	1.947	1.926	1.905	1.865	1.825	1.788	1.751	1.716
6	2.045	2.035	2.014	1.993	1.953	1.913	1.875	1.838	1.803

Inside Surface in Square Feet per Lineal Foot

Outside diam. Inches	7/32	1/4	5/16	3/8	1/2	5/8	3/4	7/8	1
1/2									
5/8									
3/4									
7/8	.1145								
1	.1473	.1309							
1 1/8	.1800	.1636							
1 1/4	.2127	.1963	.1636	.1309					
1 3/8	.2454	.2291	.1963	.1636					
1 1/2	.2782	.2618	.2291	.1963	.1309				
1 3/4	.3436	.3272	.2945	.2618	.1963				
2	.4091	.3927	.3600	.3272	.2618	.1963			
2 1/4	.4745	.4581	.4254	.3927	.3272	.2618			
2 1/2	.5400	.5236	.4909	.4581	.3927	.3272			
2 3/4	.6054	.5890	.5563	.5236	.4581	.3927			
3	.6709	.6545	.6218	.5890	.5236	.4581	.3927	.3272	.2618
3 1/4	.7363	.7199	.6872	.6545	.5890	.5236	.4581	.3927	.3272
3 1/2	.8018	.7854	.7527	.7199	.6545	.5890	.5236	.4581	.3927
3 3/4	.8672	.8508	.8181	.7854	.7199	.6545	.5890	.5236	.4581
4	.9327	.9163	.8836	.8508	.7854	.7199	.6545	.5890	.5236
4 1/4	.9981	.9817	.9490	.9163	.8508	.7854	.7199	.6545	.5890
4 1/2	1.0636	1.0472	1.0145	.9817	.9163	.8508	.7854	.7199	.6545
4 3/4	1.1290	1.1126	1.0799	1.0472	.9817	.9163	.8508	.7854	.7199
5	1.1945	1.1781	1.1454	1.1126	1.0472	.9817	.9163	.8508	.7854
5 1/4	1.2599	1.2435	1.2108	1.1781	1.1126	1.0472	.9817	.9163	.8508
5 1/2	1.3254	1.3090	1.2763	1.2435	1.1781	1.1126	1.0472	.9817	.9163
5 3/4	1.3908	1.3744	1.3417	1.3090	1.2435	1.1781	1.1126	1.0472	.9817
6	1.4563	1.4399	1.4072	1.3744	1.3090	1.2435	1.1781	1.1126	1.0472

BRIGGS' STANDARD

The nominal sizes of pipe 10 inches and under, and the pitches of the threads, were for the most part established in the British tube (called "pipe" in America) trade between 1820 and 1840. The sizes are designated roughly, according to their internal diameters.

Robert Briggs, about 1862, while Superintendent of the Pascal Iron Works, formulated the nominal dimensions of pipe up to and including 10 inches. These dimensions have been broadly spread and are widely known as "Briggs' Standard." They are as follows:

The nominal and outside diameters and pitch of thread, for sizes 10 inches and under, are given in the table of Standard Pipe, page 22, of this book.

The thread has an angle of 60° and is slightly rounded off at top and bottom so that the total height (depth), $H = \frac{0.8}{n}$, where n is the number of threads per inch.

The pitch of the threads $\left(\frac{1}{n}\right)$ increases roughly with the diameter, but in an arbitrary and irregular manner. It would be advantageous to change the pitches except for the fact that they are now firmly established.

The conically threaded ends of pipe are cut at a taper of ¾-inch diameter per foot of length (i.e., 1 in 32 to the axis of the pipe). (See Fig. 113.)

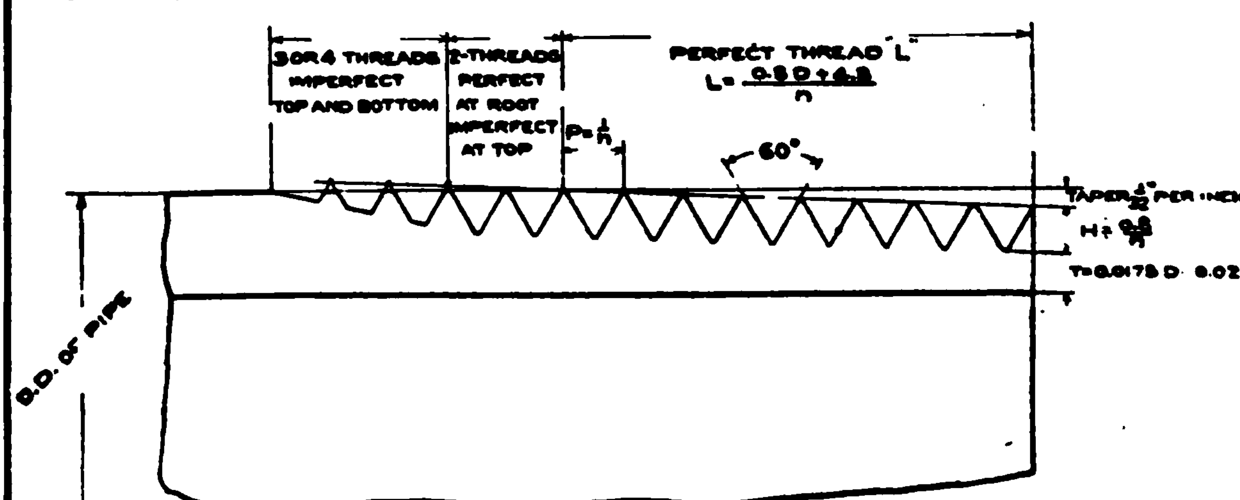


Fig. 113

The thread is perfect for a distance (L) from the end of the pipe, expressed by the rule, $L = \frac{0.8\,D + 4.8}{n}$; where D = outside diameter in inches. Then come two threads, perfect at the root or bottom, but imperfect at the top, and then come three or four threads imperfect at both top and bottom. These last do not enter into the joint at all, but are incident to the process of cutting the threads.

The thickness of the pipe under the root of the thread at the end of the pipe equals $T = 0.0175\,D + 0.025$ inch.

The above notes on Briggs' Standard were taken from Paper No. 1842, "American Practice in Warming Buildings by Steam," presented before the British Institute of Civil Engineers by Robert Briggs, member of the Institute. It is contained in the Institute Proceedings, Vol. LXXI, Session 1882–83, Part I. The substance of that paper is quoted quite fully in the report of the Committee on Standard Pipe and Pipe Threads to the American Society of Mechanical Engineers at the seventh annual meeting and is published in Vol. VIII, Paper No. 226, of their proceedings. The report was accepted by the American Society, December 29, 1886.

Briggs' Standard was adopted by the manufacturers of wrought-iron pipe and boiler tubes, October 27, 1886, and indorsed by the Manufacturers' Association of Brass and Iron, Steam, Gas and Water Work, December 8, 1886; except that the outside diameter of 9-inch pipe was changed to 9.625 inches.

By trade usage, the above rules have been extended to take in sizes up to 15 inches inclusive, except that the standard thickness is 0.375 inch, with the outside diameters given on page 22. Pipes larger than 15 inches, nominal size, are known by their outside diameter. The dimensions have also been extended to Extra Strong and Double Extra Strong Pipe, by holding the outside diameter and allowing the inside diameter to decrease according to increase in thickness. See page 25 for Extra and Double Extra Strong Pipe.

National Tube Company threads its pipe to conform to the Briggs' Standard Gages as made by the Pratt & Whitney Company of Hartford, Conn., U. S. A.

The following table gives the depth of different pipe and casing threads:

8 threads per inch	.100 inch
10 threads per inch	.080 inch
11½ threads per inch	.0696 inch
12 threads per inch	.0667 inch
14 threads per inch	.0571 inch
18 threads per inch	.0444 inch
27 threads per inch	.0296 inch

THE PHYSICAL PROPERTIES OF CARBONIC ACID

In a paper presented before the American Society of Mechanical Engineers (December, 1908) by Prof. R. T. Stewart, of the University of Pittsburgh, is given the most recent information on "The Physical Properties of Carbonic Acid and the Conditions of Its Economic Storage for Transportation." The necessity for accurate data on this subject was at that time so apparent that arrangements were made with Professor Stewart to make a special study of all the data available, and to make such experiments as were required in order to supply a sound basis for the design, manufacture and filling of carbonic acid cylinders. The results of this investigation may be found in the above article.

The tables and charts given in this paper furnish the data necessary in investigating the strength and safety of existing carbonic acid cylinders and the design of new cylinders on a safe and economical basis. The

value of these tables will be apparent when it is considered that each of these cylinders becomes, when charged, a reservoir of stored energy, which would in all probability cause loss of both life and property should rupture occur.

It is impracticable in a short space to give an abstract which would be sufficiently complete, nor is this necessary, as the complete data is available to all who are interested. The scope of Professor Stewart's paper may be judged from the following extract from the introduction:

"In Part One of this paper the tables and charts show the physical properties of pure carbon dioxide and are based upon three things: First, the average of the values obtained by Lord Rayleigh and by Leduc for the weight in grams of one liter of purified and dried carbon dioxide, CO_2, under standard conditions; second, the adjusted results which carbon dioxide differs in its physical actions from the laws of a perfect gas; and, third, the direct application of certain fundamental physical relations and of mathematical and graphical analyses.

"In Part Two is given the results of the author's experiments on commercial carbonic acid contained in commercial steel cylinders.

"In Part Three is given a rational method of designing commercial carbonic acid cylinders."

HOLDING-POWER OF BOILER-TUBES EXPANDED INTO TUBE SHEETS

(Kent's Mechanical Engineers' Pocket Book.)

Experiments by Chief Engineer W. H. Shock, U. S. N., on brass tubes 2½ inches diameter, expanded into plates ¾-inch thick, gave results ranging from 5850 to 46 000 pounds. Out of 48 tests, 5 gave figures under 10 000 pounds, 12 between 10 000 and 20 000 pounds, 18 between 20 000 and 30 000 pounds, 10 between 30 000 and 40 000 pounds, and 3 over 40 000 pounds.

Experiments by Yarrow & Co., on steel tubes, 2 to 2¼ inches diameter, gave results similarly varying, ranging from 7900 to 41 715 pounds, the majority ranging from 20 000 to 30 000 pounds. In 15 experiments on 4- and 5-inch tubes the strain ranged from 20 720 to 68 040 pounds. Beading the tube does not necessarily give increased resistance, as some of the lower figures were obtained with beaded tubes. (See paper on Rules Governing the Construction of Steam Boilers, Trans. Engineering Congress, Section G, Chicago, 1893).

The Slipping Point of Rolled Boiler-tube Joints

(O. P. Hood and G. L. Christensen, Trans. A. S. M. E., 1908.)

When a tube has started from its original seat, the fit may be no longer continuous at all points and a leak may result, although the ultimate holding power of the tube may not be impaired. A small movement of the tube under stress is then the preliminary to a possible leak, and it is of interest to know at what stress this slipping begins.

As results of a series of experiments with tube sheets of from ½ inch to 1 inch in thickness, and with straight and tapered tube seats, the

authors found that the slipping point of a 3-inch 12-gage Shelby cold-drawn tube rolled into a straight, smooth machined hole in a 1-inch sheet occurs with a pull of about 7000 pounds. The frictional resistance of such tubes is about 750 pounds per square inch of tube-bearing area in sheets 5/8 inch and 1 inch thick.

Various degrees of rolling do not greatly affect the point of initial slip, and for higher resistances to initial slip other resistance than friction must be depended upon. Cutting a 10 pitch square thread in the seat, about 0.01 inch deep, will raise the slipping point to three or four times that in a smooth hole. In one test this thread was made 0.015 inch deep in a sheet 1 inch thick, giving an abutting area of about 1.4 square inches and a resistance to initial slip of 45 000 pounds. The elastic limit of the tube was reached at about 34 000 pounds.

Where tubes give trouble from slipping and are required to carry an unusual load, the slipping point can be easily raised by serrating the tube seat by rolling with an ordinary flue expander, the rolls of which are grooved about 0.007 inch deep and 10 grooves to the inch. One tube thus serrated had its slipping point raised between three and four times its usual value.

THERMAL EXPANSION OF IRON AND STEEL TUBES

A number of samples of the various metals used in the manufacture of seamless and welded tubes were recently submitted to the Bureau of Standards, Washington, D. C., for determinations of the coefficients of expansion within the range of temperatures common to boiler practice. The mean coefficient of expansion (a) of these materials between 0° C. and 200° C. was found to be:

	Chemical analyses				(a)
	Carbon	Phosphorus	Manganese	Sulphur	
Charcoal iron	Trace	.049	Trace	.020	.00001235
Bessemer steel	.07	.132	.40	.052	.00001258
Seamless O. H. steel (hot finished)	.12	.0145	.51	.035	.00001239

The length of a tube at t degrees Centigrade is:

$$L_t = L_0 (1 + at).$$

The report of this investigation remarks:

"As might have been expected from the known behavior of metals nearly all the specimens appeared to expand faster at higher than at low temperatures. The measurements indicate that, throughout the range from 0° C. to 200° C., the values of the coefficients (a) might increase from as much as about 1.3 per cent. less than to about as much as 1.3 per cent. greater than the values given in the above table."

STRENGTH OF TUBES, PIPES, AND CYLINDERS UNDER INTERNAL FLUID PRESSURE

In order to arrive at some definite conclusion as to what formula or formulæ should be used for calculating the strength of tubes, pipes, and cylinders subjected to internal fluid pressure, the different published formulæ have been investigated and compared. These are five in number; namely, the Common Formula, and those by Barlow, Lamé, Clavarino, and Birnie.

These formulæ have been put into the simplest form for application to tubes, pipes, and cylinders, and are reduced to a common notation for the sake of making an easy comparison. The notation used is as follows:

D_1 = outside diameter in inches;
D_2 = inside diameter in inches;
t = thickness of wall in inches;
p = internal gage pressure, or difference between internal and external fluid pressures, in pounds per square inch;
f = fiber stress in the wall in pounds per square inch.

The formulæ here given are for the usual conditions of practice, namely, where the external pressure is atmospheric and the internal pressure is expressed as gage pressure. They are also applicable to cases where the external pressure is not excessive by taking p as the difference between the internal and external pressures.

In all that follows it is assumed that the length of the tube or pipe relative to its diameter is sufficiently great to eliminate the influence of end support tending to prevent rupture.

Nature of Stress in a Tube Wall. An internal fluid pressure may give rise (1) to a circumferential stress within the wall of a tube or pipe, or (2) to both a circumferential and a longitudinal stress acting jointly. In either case the tube wall is under radial compressive stress, as indicated by the arrows, Figs. 114 and 115.

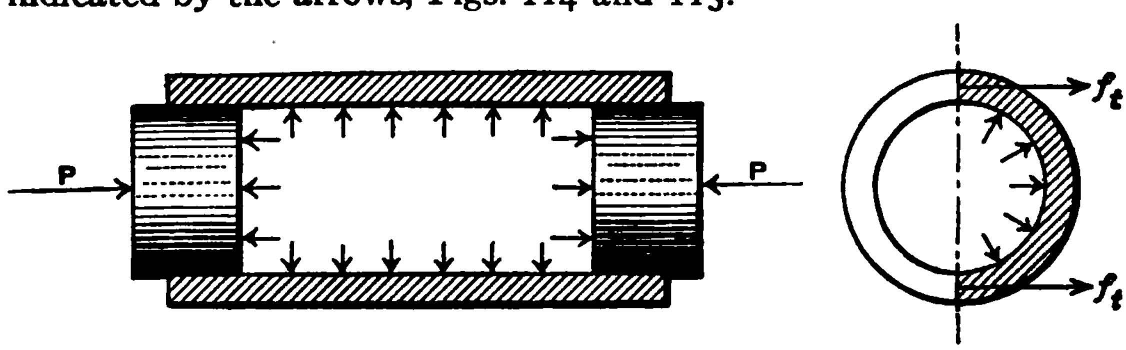


Fig. 114

Fig. 114 illustrates a tube with frictionless plungers fitted into its ends, the plungers being kept in place by the external forces, P, P, which exactly balance the internal fluid pressure tending to force them outward. In this case the tube wall is subjected only to the internal forces shown as acting at right angles to its inner surface. It is obvious that these

forces can give rise to radial and circumferential stresses only in the tube wall. The value of the circumferential stress, f_t, in pounds per square inch, is

$$f_t = p \frac{D_2}{D_1 - D_2} = \frac{pD_2}{2t} \tag{1}$$

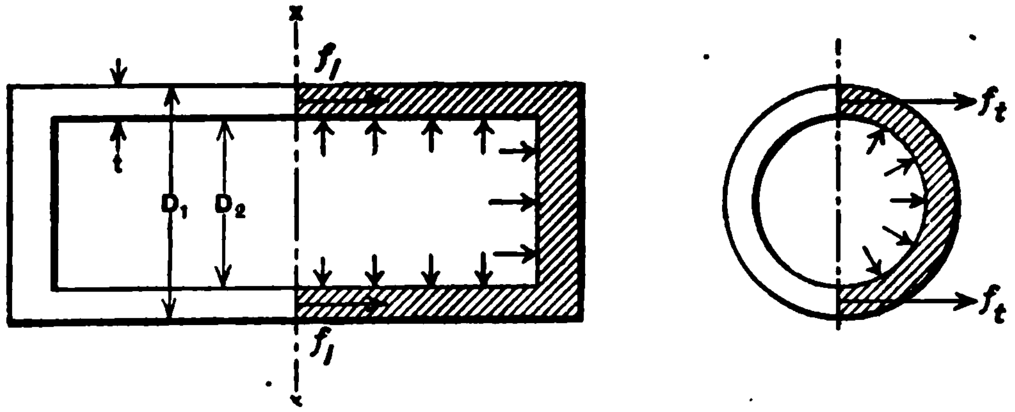


Fig. 115

Fig. 115 illustrates the ordinary case of a tube or pipe with both ends closed. In this case the tube wall, as in Fig. 114, is subjected to the circumferential stress, f_t, along with the radial stress, and at the same time is subjected to the longitudinal stress, f_l. The longitudinal stress is caused by the internal fluid pressure tending to force the attached heads outward and expressed in pounds per square inch is

$$f_l = p \frac{D_2^2}{4 (D_2 + t)t}. \tag{2}$$

When the thickness of wall, t, is relatively small with respect to the diameter, the longitudinal stress becomes approximately

$$f_l = \frac{pD_2}{4t}, \tag{3}$$

or one-half the corresponding circumferential stress.

Common Formula. This is the formula generally found in books on mechanics. It is based on the condition that the tube wall is subjected to circumferential stress only (Fig. 114), and assumes (1) that the material of the tube wall is devoid of elasticity, and (2) that the stress is the same on all the circumferential fibers from the innermost to the outermost. These assumptions are only approximately true for tubes of comparatively thin walls, and are greatly in error for tubes having very thick walls.

Using the notation as given above, the formula is

$$\frac{p}{f} = 2\frac{t}{D_2}; \quad p = 2f\frac{t}{D_2}; \quad t = \frac{1}{2} D_2 \frac{p}{f}; \quad f = \frac{1}{2} D_2 \frac{p}{t}. \tag{4}$$

Referring to the curves, Figs. 116 and 117, it will be seen that the Common Formula gives quite close results for comparatively thin walls when used for the conditions shown in Fig. 114, for which Birnie's Formula is theoretically correct. The error increases as the thickness of wall becomes relatively greater, reaching ten per cent for a thickness ratio,

$\frac{t}{D_1}$, of about 0.05. For thick walls the error is great; for example, when $\frac{t}{D_1}$ equals 0.25 the value of $\frac{p}{f}$ is about one hundred per cent in error. It should be observed when applying the Common Formula to this case that the error is always on the side of danger.

For the conditions shown in Fig. 115, that is, when the tube is subjected to the stresses due to an internal fluid pressure acting jointly on the tube wall and its closed ends, for which Clavarino's Formula is theoretically correct, the curves show for a thickness ratio, $\frac{t}{D_1}$, less than 0.07, that the Common Formula errs on the side of safety, the greatest error being about twelve per cent; while for thickness ratios greater than 0.07 the error is on the side of danger, reaching ten per cent for a thickness ratio of 0.1 and about one hundred per cent for a ratio of 0.25.

Barlow's Formula. This formula assumes (1) that because of the elasticity of the material, the different circumferential fibers will have their diameters increased in such a manner as to keep the area of cross-section constant, and (2) that the length of the tube is unaltered by the internal fluid pressure. As neither of these assumptions is theoretically correct, this formula can give only approximately correct results. Using the notation given above, this formula is

$$\frac{p}{f} = 2\frac{t}{D_1}; \quad p = 2f\frac{t}{D_1}; \quad t = \frac{1}{2}D_1\frac{p}{f}; \quad f = \frac{1}{2}D_1\frac{p}{t}. \tag{5}$$

It should be observed that while Barlow's Formula is similar in form to the Common Formula, it gives results that are quite different when applied to tubes, pipes, and cylinders having walls of considerable thickness. This is due to the fact that Barlow's Formula is expressed in terms of the outside diameter, D_1, whereas the Common Formula is expressed in terms of the inside diameter, D_2.

Referring to the curves, Figs. 116 and 117, it will be seen that Barlow's Formula gives quite close results when used for the condition shown in Fig. 114, for which Birnie's Formula is theoretically correct. The curves show for the entire practical range of thickness ratios that the error in values of $\frac{p}{f}$, for this case, does not exceed three per cent, the error throughout the whole practical range being on the side of safety. This, then, is the best of the simple theoretical formulæ for application to the case illustrated in Fig. 114.

For the conditions shown in Fig. 115, namely, when the tube is subjected to the stresses due to an internal fluid pressure acting jointly on the tube wall and its closed ends, for which Clavarino's Formula is theoretically correct, the curves show that Barlow's Formula gives values of $\frac{p}{f}$ whose errors range from fifteen per cent for tubes, pipes, and cylinders having thin walls to ten per cent for those having thick walls, the error being on the side of safety for all practical thickness ratios.

Lamé's Formula. This formula is meant to apply to the conditions shown in Fig. 115. Each material particle of the tube wall is supposed to be subjected to the radial compression, and the circumferential and longitudinal tensions due to an internal fluid pressure acting jointly on the tube wall and its closed ends; and the material of the tube wall is supposed to be elastic under these actions. Lamé's Formula, however, ignores the "Coefficient of Lateral Contraction," known as "Poisson's Ratio," and consequently is not theoretically correct.

Using the notation as given above, this formula is

$$\frac{p}{f}=\frac{D_1^2-D_2^2}{D_1^2+D_2^2};\quad p=\frac{D_1^2-D_2^2}{D_1^2+D_2^2}f;\quad D_2=D_1\sqrt{\frac{f-p}{f+p}};\quad D_1=D_2\sqrt{\frac{f+p}{f-p}}. \tag{6}$$

Referring to the curves, Figs. 116 and 117, it will be seen that Lamé's Formula, which is meant to apply to the conditions for which Clavarino's Formula is theoretically correct, gives for thickness ratios, $\frac{t}{D_1}$, less than 0.15, an error on the side of safety, the error having a maximum value of about fourteen per cent when $\frac{t}{D_1}$ equals 0.01. For thickness ratios greater than 0.15 the error is on the side of danger, reaching ten per cent for a ratio of about 0.23.

Clavarino's Formula. In this formula, as in Lamé's Formula, each material particle of the tube wall is supposed to be subjected to the radial compression and the circumferential and longitudinal tensions due to an internal fluid pressure acting jointly on the tube wall and its closed ends; and the material is supposed to be elastic under these actions. Unlike Lamé's Formula, however, this formula expresses the true stresses in the tube wall as based upon the "Coefficient of Lateral Contraction," known as "Poisson's Ratio," and is consequently theoretically correct for the conditions shown in Fig. 115, providing the stress on the most strained fiber does not exceed the elastic limit of the material.

Using the notation given above and assuming the value of the "Coefficient of Lateral Contraction," for tube steel to be 0.3, this formula is

$$\frac{p}{f}=\frac{10\,(D_1^2-D_2^2)}{13\,D_1^2+4\,D_2^2};\quad p=\frac{10\,(D_1^2-D_2^2)}{13\,D_1^2+4\,D_2^2}f;\quad D_1=D_2\sqrt{\frac{10f+4p}{10f-13p}};$$

$$D_2=D_1\sqrt{\frac{10f-13p}{10f+4p}}. \tag{7}$$

This theoretically correct formula for the conditions shown in Fig. 115 has the disadvantage that it is difficult to apply directly in making calculations. In order to remove this difficulty the table on page 220 has been prepared, by means of which any desired calculation can be as

readily made by Clavarino's Formula as by any of the simpler formulæ. The entries of this table are the values in Clavarino's Formula of the factor

$$\frac{10\,(D_1^2 - D_2^2)}{13\,D_1^2 + 4\,D_2^2} = k.$$

It will be observed that these factors are tabulated for thickness ratios, $\frac{t}{D_1}$, from 0.01 to 0.3, advancing by thousandths. Thus for a wall thickness, t, of 0.25 inch and an outside diameter, D_1, of ten inches, the thickness ratio, $\frac{t}{D_1}$, would be 0.25 divided by 10, or 0.025. The required factor corresponding to this thickness ratio is 0.0587 and is found in the column headed 0.005 opposite 0.02 in column one. Similarly for an outside diameter of four inches and a wall thickness of 0.5 inch, the thickness ratio would be 0.125 and the corresponding internal pressure factor is 0.2869.

If we designate the value of any tabular factor by k, then it is obvious that Clavarino's Formula may be written

$$\frac{p}{f} = k; \quad p = kf; \quad f = \frac{p}{k}. \tag{8}$$

This table is well adapted to the ready solution of problems involving the strength and safety of a tube, pipe, or cylinder which is subjected to the stresses due to an internal fluid pressure acting jointly on its wall and closed ends, as illustrated in Fig. 115.

Problem 1. *Required the safe working fluid pressure* p, Fig. 115, when the outside diameter, D_1, equals four inches; thickness of wall, t, equals 0.5 inch; and the working fiber stress of the steel, f, equals 10 000 pounds.

Solution. (1) The thickness ratio, $\frac{t}{D_1}$, equals 0.125; (2) the corresponding tabular factor, k, is found from the table, page 220, to be 0.2869; and (3) the required safe working fluid pressure, p, equals kf (equation 8), or 0.2869 times 10 000, or 2869 pounds per square inch.

Problem 2. *Required the fiber stress,* f, in the wall of a cylinder, Fig. 115, when the outside diameter, D_1, equals 5.5 inches; the thickness of wall, t, equals 0.25 inch; and the working fluid pressure, p, equals 1500 pounds per square inch.

Solution. (1) The thickness ratio, $\frac{t}{D_1}$, equals 0.045; (2) the corresponding tabular factor, k, is found from table on page 220, to be 0.1054; and (3) the required fiber stress, f, equals $\frac{p}{k}$ (equation 8), or 1500 divided by 0.1054, or 14 200 pounds per square inch.

Problem 3. *Required the thickness of wall,* t, Fig. 115, when the outside diameter, D_1, equals eight inches; the working fiber stress of the steel,

f, equals 15 000 pounds per square inch; and the working fluid pressure, p, equals 2000 pounds per square inch.

Solution. (1) The factor, k, equals $\frac{p}{f}$ (equation 8) or 2000 divided by 15 000 or 0.133; (2) the value of the thickness ratio, $\frac{t}{D_1}$, corresponding to this value of k is found from the table on page 220 to be 0.057; and (3) the required thickness will result from multiplying this thickness ratio, $\frac{t}{D_1}$, by the outside diameter, D_1, or 0.057 times 8 equals 0.456 inch.

NOTE. When the inside diameter, D_2; the internal pressure, p; and the working fiber stress, f, are given and it is required to find the thickness of wall, t: proceed by finding first the value of the outside diameter, D_1, by means of equation (7), after which the required thickness may be had by taking one-half the difference of the outside and inside diameters, or

$$t = \frac{D_1 - D_2}{2}. \tag{9}$$

Birnie's Formula. This formula is based upon the conditions illustrated in Fig. 114. In its derivation, precisely the same assumptions are made as for Clavarino's Formula with the single exception that the longitudinal stress, f_l, due to the internal fluid pressure acting upon attached heads is assumed not to exist. Birnie's Formula consequently is theoretically correct for tubes, pipes, and cylinders that are subjected to an internal fluid pressure in such a manner as not to give rise to longitudinal stress in the wall; provided the stress on the most strained fiber does not exceed the elastic limit of the material.

Using the same notation as before and assuming the value of the "Coefficient of Lateral Contraction" for steel to be 0.3, this formula is

$$\frac{p}{f} = \frac{10\,(D_1^2 - D_2^2)}{13\,D_1^2 + 7\,D_2^2}; \quad p = \frac{10\,(D_1^2 - D_2^2)}{13\,D_1^2 + 7\,D_2^2}f; \quad D_1 = D_2\sqrt{\frac{10f + 7p}{10f - 13p}};$$

$$D_2 = D_1\sqrt{\frac{10f - 13p}{10f + 7p}}. \tag{10}$$

Birnie's Formula, like Clavarino's Formula, has the disadvantage of being difficult to apply directly in making calculations. In order to remove this difficulty the table on page 221 has been prepared, the entries being the values in Birnie's Formula of the factor

$$\frac{10\,(D_1^2 - D_2^2)}{13\,D_1^2 + 7\,D_2^2} = k.$$

This table is used in a manner precisely similar to the table of factors for Clavarino's Formula. See explanation and solution of problems on page 216.

Comparison of Internal Fluid Pressure Formulæ for Tubes, Pipes and Cylinders

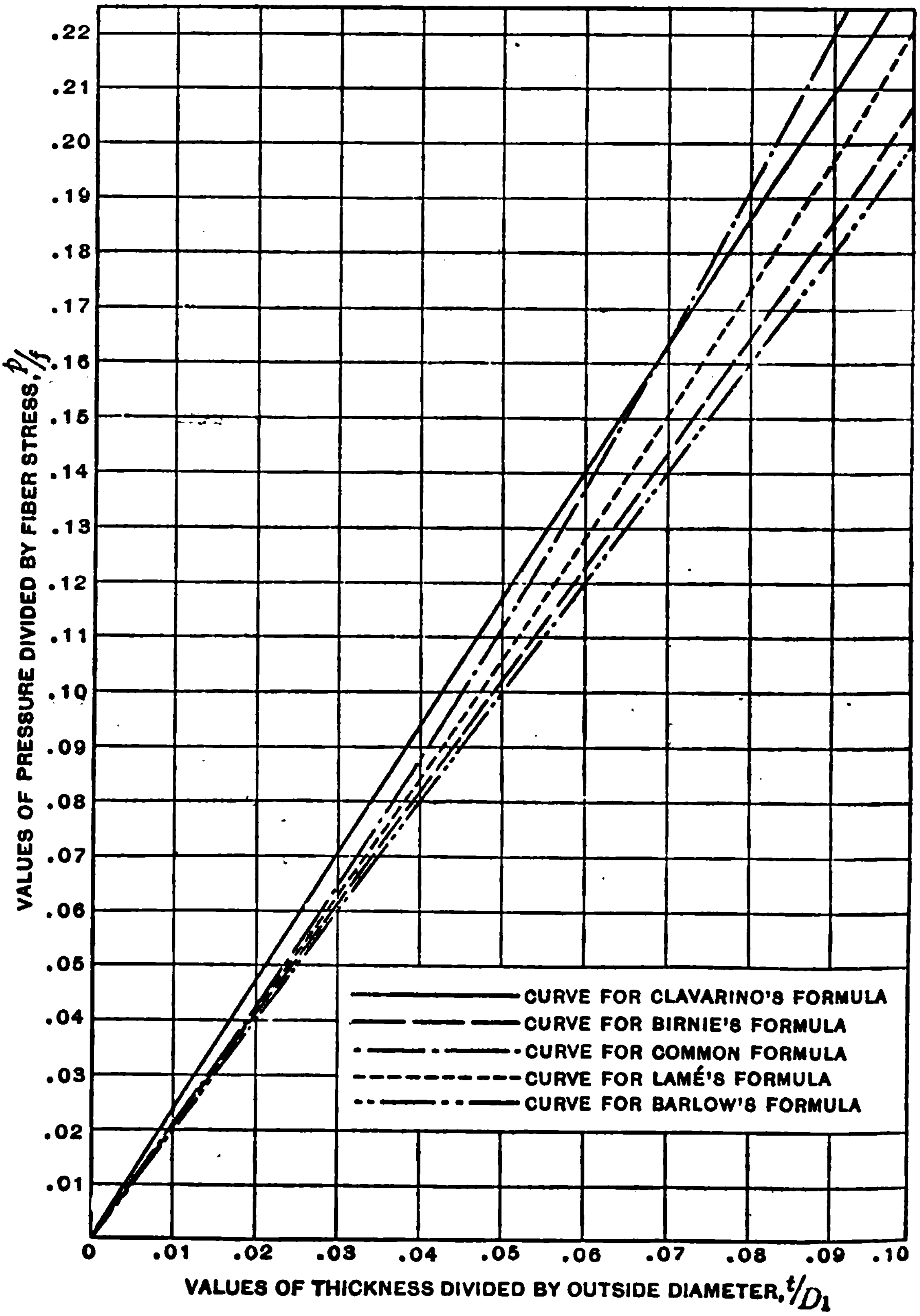


Fig. 116

Comparison of Internal Fluid Pressure Formulæ for Tubes, Pipes and Cylinders (Concluded)

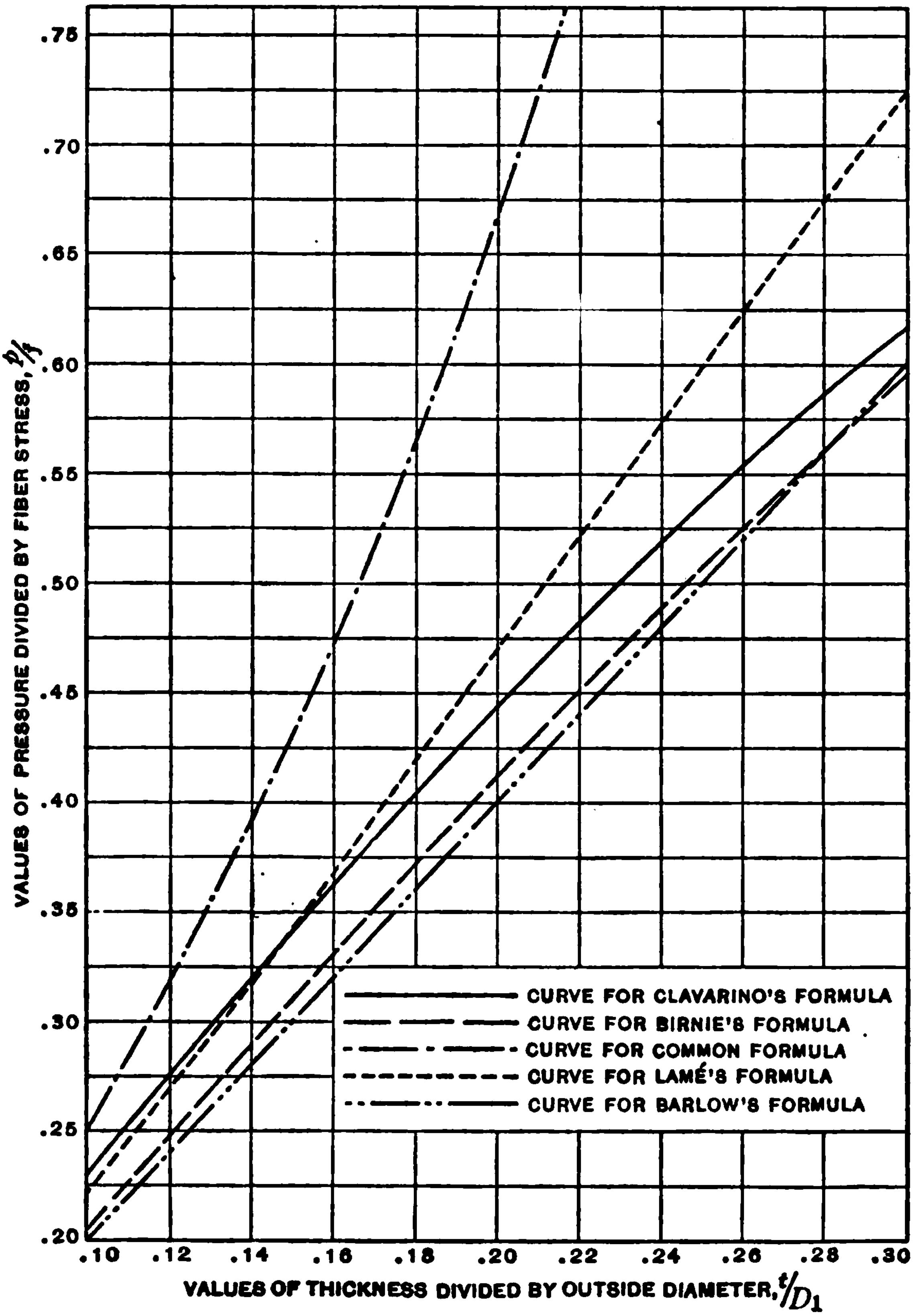


Fig. 117

Internal Fluid Pressure Factors, k, for Conditions shown in Fig. 115

[Calculated by Clavarino's Formula, assuming for steel a "Coefficient of Lateral Contraction" (Poisson's Ratio) equal 0.3.]

Rule. Divide thickness of tube or pipe by its outside diameter, both being expressed in inches, then multiply the tabular value corresponding to this quotient by the working fiber stress in pounds per square inch. The result will be the safe internal pressure in pounds per square inch.

For further use of table, see page 216.

t/D_1	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
.01	.0235	.0259	.0282	.0306	.0329	.0352	.0376	.0399	.0423	.0446
.02	.0470	.0493	.0517	.0540	.0564	.0587	.0610	.0634	.0657	.0681
.03	.0704	.0727	.0751	.0774	.0797	.0821	.0844	.0867	.0891	.0914
.04	.0937	.0961	.0984	.1007	.1031	.1054	.1077	.1100	.1123	.1147
.05	.1170	.1193	.1216	.1239	.1263	.1286	.1309	.1332	.1355	.1378
.06	.1401	.1424	.1448	.1471	.1494	.1517	.1540	.1563	.1586	.1609
.07	.1632	.1655	.1678	.1700	.1723	.1746	.1769	.1792	.1815	.1838
.08	.1861	.1883	.1906	.1929	.1952	.1974	.1997	.2020	.2043	.2065
.09	.2088	.2111	.2133	.2156	.2178	.2201	.2223	.2246	.2269	.2291
.10	.2314	.2336	.2358	.2381	.2403	.2425	.2448	.2470	.2493	.2515
.11	.2537	.2559	.2582	.2604	.2626	.2648	.2670	.2692	.2715	.2737
.12	.2759	.2781	.2803	.2825	.2847	.2869	.2890	.2912	.2934	.2956
.13	.2978	.3000	.3022	.3043	.3065	.3087	.3108	.3130	.3152	.3173
.14	.3195	.3216	.3238	.3259	.3281	.3302	.3323	.3345	.3366	.3388
.15	.3409	.3430	.3451	.3472	.3494	.3515	.3536	.3557	.3578	.3599
.16	.3620	.3641	.3662	.3683	.3704	.3724	.3745	.3766	.3787	.3808
.17	.3828	.3849	.3869	.3890	.3910	.3931	.3951	.3972	.3992	.4013
.18	.4033	.4053	.4073	.4094	.4114	.4134	.4154	.4174	.4194	.4214
.19	.4234	.4254	.4274	.4294	.4314	.4333	.4353	.4373	.4393	.4412
[illegible]	.4432	.4452	.4471	.4490	.4510	.4529	.4548	.4568	.4587	.4606
.21	.4626	.4645	.4664	.4683	.4702	.4721	.4740	.4758	.4777	.4796
.22	.4815	.4834	.4852	.4871	.4889	.4908	.4926	.4945	.4964	.4982
.23	.5001	.5019	.5037	.5055	.5073	.5091	.5109	.5127	.5145	.5163
.24	.5181	.5199	.5216	.5234	.5252	.5269	.5287	.5304	.5322	.5340
.25	.5357	.5374	.5391	.5408	.5426	.5443	.5460	.5477	.5494	.5511
.26	.5528	.5545	.5561	.5578	.5594	.5611	.5628	.5644	.5661	.5677
.27	.5694	.5710	.5726	.5742	.5758	.5774	.5790	.5806	.5822	.5838
.28	.5854	.5870	.5885	.5901	.5916	.5932	.5947	.5963	.5978	.5994
.29	.6009	.6024	.6039	.6054	.6069	.6084	.6099	.6114	.6129	.6143
.30	.6158	.6173	.6187	.6201	.6216	.6230	.6244	.6259	.6273	.6287

Internal Fluid Pressure Factors, *k*, for Conditions shown in Fig. 114

[Calculated by Birnie's Formula, assuming for steel a "Coefficient of Lateral Contraction" (Poisson's Ratio) equal 0.3.]

Rule. Divide thickness of tube or pipe by its outside diameter, both being expressed in inches, then multiply the tabular value corresponding to this quotient by the working fiber stress in pounds per square inch. The result will be the safe internal pressure in pounds per square inch.

For further use of table, see page 217.

t/D_1	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
.01	.0201	.0221	.0241	.0261	.0282	.0302	.0322	.0342	.0363	.0383
.02	.0403	.0423	.0444	.0464	.0485	.0505	.0525	.0546	.0566	.0586
.03	.0607	.0627	.0648	.0668	.0689	.0709	.0730	.0750	.0771	.0791
.04	0812	.0832	.0853	.0873	.0894	.0915	0935	.0956	.0976	.0997
.05	.1018	.1038	.1059	.1080	.1100	.1121	.1142	.1163	.1183	.1204
.06	.1225	.1245	.1266	.1287	.1308	.1329	.1349	.1370	.1391	.1412
.07	.1433	.1453	.1474	.1495	.1516	.1537	.1558	.1579	.1599	.1620
.08	.1641	.1662	.1683	.1704	.1725	.1746	.1767	.1787	.1808	.1829
.09	.1850	.1871	.1892	.1913	.1934	.1955	.1976	.1997	.2018	.2039
.10	.2059	.2080	.2101	.2122	.2143	.2164	.2185	.2206	.2227	.2248
.11	.2269	.2290	.2311	.2332	.2353	.2374	.2395	.2416	.2437	.2457
.12	.2478	2499	.2520	.2541	.2562	.2583	.2604	.2625	.2646	.2667
.13	.2688	.2708	.2729	.2750	.2771	.2792	.2813	.2834	.2854	.2875
.14	.2896	.2917	.2938	.2959	.2979	.3000	.3021	.3042	.3062	.3083
.15	.3104	.3125	.3145	.3166	.3187	.3208	.3228	.3249	.3270	.3290
.16	.3311	.3332	.3352	.3373	.3393	.3414	.3434	.3455	.3476	.3496
.17	.3517	.3537	.3558	.3578	.3598	.3619	.3639	.3660	.3680	.3700
.18	.3721	.3741	.3761	.3782	.3802	.3822	.3842	.3863	.3883	.3903
.19	.3923	.3943	.3963	.3983	.4003	.4024	.4044	.4064	.4084	.4104
.20	.4124	.4144	.4163	.4183	.4203	.4223	.4243	.4262	.4282	.4302
.21	.4322	.4341	.4361	.4380	.4400	.4419	.4439	.4459	.4478	.4498
.22	.4517	.4536	.4556	.4575	.4594	.4613	.4633	.4652	.4671	.4690
.23	.4710	.4729	.4748	.4767	.4785	.4804	.4823	.4842	.4861	.4880
.24	.4899	.4918	.4936	.4955	.4973	.4992	.5010	.5029	.5048	.5066
.25	.5085	.5103	.5121	.5139	.5157	.5176	.5194	.5212	.5230	.5248
.26	.5266	.5284	.5302	.5320	.5338	.5355	.5373	.5391	.5409	.5427
.27	.5444	.5462	.5479	.5496	.5514	.5531	.5548	.5566	.5583	.5600
.28	.5617	.5634	.5651	.5668	.5685	.5702	.5718	.5735	.5752	.5769
.29	.5786	.5802	.5818	.5835	.5851	.5867	.5884	.5900	.5916	.5933
.30	.5949	.5965	.5981	.5996	.6012	.6028	.6044	.6059	.6075	.6091

Strength of Commercial Tubes, Pipes and Cylinders to Resist Internal Fluid Pressures

In the preceding portion of this chapter there appears a full statement of the basis of each of the five theoretical formulæ for the strength of tubes, pipes, and cylinders when subjected to internal fluid pressures, together with a comparison of results obtained by their use. One or other of these formulæ, taken apparently at random, has often been used without sufficient understanding of their application to practical conditions. It is the purpose of what follows to illustrate the proper application of these formulæ making use of the results of hydrostatic tests recently made on commercial pipes at one of the mills of the National Tube Company.

Yield Point Tests on Commercial Pipe. Tests were made under Clavarino's condition, Fig. 115, on 195 specimens of 10-inch and 279 specimens of 12-inch lap-welded steel pipes, all of which were made up into cylinders with heads welded to the pipe. The hydrostatic pressure was raised until the yield point of the material was reached. The unit stresses on the most strained fibers were then calculated by means of Clavarino's formula, the pipes having been measured by micrometer, before welding in the head, to determine the least thickness of wall.

The average results of the yield points of the most strained fibers of the material constituting these pipes when compared with the average yield point of tensile test specimens cut from about 400 similar pipes may be summarized as follows:

Outside diameter of pipe, inches..........	10.00	12.00
Least thickness of wall, inch..............	.172	.164
Hydrostatic pressure at yield point, pounds per square inch......................	1 435	1 195
Yield point by Clavarino's formula, pounds per square inch......................	35 600	37 100
Yield point, average of tensile tests, pounds per square inch......................	37 000	37 000
Apparent error in yield point by Clavarino's formula...........................	−3.8%	+0.3%

This summary of the average results of 474 tests is a very satisfactory confirmation of the accuracy of Clavarino's Formula when applied to commercial steel pipes for the conditions under which the formula theoretically applies.

Other tests show that when the heads are attached to the pipe, as in Fig. 115, it lengthens upon application of an internal fluid pressure, and that when the heads are held independently, as in Fig. 114, it shortens in accord respectively with the assumptions which constitute the basis of Clavarino's and Birnie's formulæ regarding change of length under internal fluid pressure.

Applicability of Clavarino's and Birnie's Formulæ. The above summary of results of tests on pipes shows that Clavarino's formula is applicable to commercial wrought steel pipe for the condition shown in

Fig. 115, when the yield point of the most strained fiber is not exceeded and the least thickness of wall is accurately known.

Tests made at the Watertown Arsenal in 1892-3-4-7 and 1902 on sections of steel guns show that Birnie's formula for the condition shown in Fig. 114, when applied up to the elastic limit of the most strained fiber, gives results which agree with the results of direct tests that are within the ordinary range of experimental error. These Watertown Arsenal tests were all made on tubes the material and dimensions of which were uniform to a degree obtainable only by boring and turning from forgings of the choicest portion of selected ingots.

It is apparent that any variation below the nominal or average value in strength of material, thickness of wall and efficiency of joint in welded pipe, or above the nominal in diameter, will give results which err on the side of danger when making use of either Clavarino's or Birnie's formulæ. These formulæ then should be restricted in their use to certain classes of seamless tubes and cylinders and to critical examinations of ordinary tubes, pipes and cylinders, when exact results are desired and sufficiently accurate data are available.

For all ordinary calculations of strength of commercial tubes, pipes and cylinders Barlow's simple approximate formula is preferable.

Bursting Tests of Commercial Tubes and Pipes. The tables, pages 225-226, show the average results of several hundred tests of commercial tubes and pipes, all of which were burst by hydrostatic pressure at one of the mills of the National Tube Company.

Of the steel tubes and pipes, 95 per cent was made by this Company, while 86 per cent of the wrought iron pipe tested was obtained by purchase in the open market.

The average ultimate tensile strength of pipe steel is 57 000 pounds per square inch, whether taken in the direction of rolling or transversely thereto, while that of the seamless steel tested is 60 000 pounds per square inch. No tensile tests were made of the material of the wrought iron pipes.

An examination of these tables will lead to the following general conclusions:

1. In commercial welded pipe the variations in thickness of wall, perfection of weld, etc., give rise to variations in bursting strength of sufficient magnitude to render unnecessary any consideration of Clavarino's or Birnie's condition of head support as shown in Figs. 115 and 114, respectively.

2. The relative strengths of steel pipes and tubes, when using Barlow's Formula and basing the calculations on average diameter, thickness of wall and ultimate tensile strength of material, are as follows: For butt-welded steel pipe, 73 per cent; for lap-welded steel pipe, 92 per cent; and for seamless steel tubes, approximately 100 per cent.

In steel pipe, then, the strength of the butt-weld is about 80 per cent of that of the lap-weld.

3. The relative strengths of wrought iron and steel pipe, from the accompanying tables, are as follows: Butt-welded wrought-iron pipe is

70 per cent as strong as similar butt-welded steel pipe; and lap-welded wrought iron pipe is 60 per cent as strong as similar lap-welded steel pipe.

Applicability of Barlow's Formula. Of the five formulæ considered in this chapter that by Barlow is the best suited for all ordinary calculations pertaining to the bursting strength of commercial tubes, pipes and cylinders.

The theoretical error on the side of safety resulting from its use will generally not exceed the actual combined error on the side of danger when using either Birnie's or Clavarino's formula due to the ordinary range of variation in the thickness of wall, strength of the material, etc., when applied to the ordinary commercial product.

This is true, at least up to the yield point of the material, for any ratio of thickness of wall to outside diameter less than three-tenths. In this respect Barlow's formula is very superior to the common approximate formula which gives errors that are absurdly large on the side of danger for very thick walls. See Fig. 117.

For certain classes of seamless tubes and cylinders and for critical examinations of welded pipe, where the least thickness of wall, yield point of material, etc., are known with accuracy, and close results are desired, see Clavarino's formula and Birnie's equations (7) and (10).

For all ordinary calculations pertaining to the bursting strength of commercial tubes, pipes and cylinders use Barlow's Formula, which is

$$\frac{p}{f} = 2\frac{t}{D}; \quad p = 2f\frac{t}{D}; \quad t = \frac{1}{2}D\frac{p}{f}; \quad f = \frac{1}{2}D\frac{p}{t}$$

Where D = outside diameter, inches;
t = average thickness of wall, inches;
p = internal fluid pressure, pounds per square inch;
f = working or safe fiber stress, pounds per square inch.
When n = safety factor as based on ultimate strength then
$f = 40\,000/n$ for butt-welded steel pipe;
$= 50\,000/n$ for lap-welded steel pipe;
$= 60\,000/n$ for seamless steel tubes;
$= 28\,000/n$ for wrought iron pipe.

These average values of f are based upon the accompanying tables of bursting tests of commercial tubes and pipes. They are intended for substitution in Barlow's Formula in case more exact data for the working fiber stress are not at hand.

Bursting Tests of Commercial Tubes and Pipes

(Tests made by National Tube Company.)

Size		Number of pieces burst	Nominal external diameter, inches	Average thickness of walls, inch	Bursting pressures pounds per square inch			Head condition	See note below	Average fiber stress by Barlow's formula	Class of material
					Minimum	Maximum	Average				
Steel — butt-welded	1/8	10	.405	.066	11 840	17 320	14 266	C	1	44 011	Standard pipe
	1/4	10	.540	.085	8 830	14 680	12 206	C	1	38 645	Standard pipe
	3/8	10	.675	.088	5 850	13 030	10 330	C	1	39 272	Standard pipe
	1/2	10	.840	.101	11 380	16 310	14 038	C	0	58 163	Standard pipe
	3/4	10	1.050	.109	7 150	9 150	8 020	C	0	38 657	Standard pipe
	1	10	1.315	.131	4 500	8 800	6 990	C	0	35 085	Standard pipe
	1 1/4	10	1.660	.139	4 400	7 300	5 808	C	0	34 603	Standard pipe
	1 1/4	15	1.660	.140	5 500	11 900	7 700	C	1	45 215	Redrawn
	1 1/2	10	1.900	.143	3 000	6 100	4 960	C	0	33 031	Standard pipe
	2	11	2.375	.149	3 830	6 060	4 951	C	0	40 485	Standard pipe
	2 1/2	10	2.875	.198	4 310	5 740	5 134	C	0	37 351	Standard pipe
	3	10	3.500	.204	4 650	6 370	5 398	C	0	46 234	Standard pipe
	1 1/4	10	1.660	.180	7 910	14 280	10 514	C	0	48 922	Extra strong
	2	10	2.375	.213	7 250	8 940	8 238	C	0	45 935	Extra strong
	2	10	2.375	.220	6 160	8 920	7 661	C	0	41 347	Extra strong
	2	10	2.375	.445	8 500	18 314	14 992	C	0	40 023	XX strong
						General average				41 686	
Steel — lap-welded	2	10	2.375	.155	4 890	7 940	6 645	C	1	50 962	Standard pipe
	2	10	2.375	.182	4 860	10 060	7 361	C	0	47 889	Standard pipe
	3	10	3.500	.210	3 830	8 200	6 368	C	7	53 560	Standard pipe
	4	10	4.500	.232	4 810	5 680	5 249	C	1	51 462	Standard pipe
	5	10	5.563	.258	3 410	5 260	4 538	C	1	48 882	Standard pipe
	6	5	6.625	.275	2 450	5 210	4 088	C	0	49 286	Standard pipe
	6	5	6.625	.275	3 170	4 760	3 666	B	0	44 106	Standard pipe
	10	5	10.750	.349	3 560	4 730	4 290	C	1	66 080	Standard pipe
	10	5	10.750	.347	2 770	3 940	3 396	B	2	52 692	Standard pipe
	2	10	2.375	.218	2 500	9 870	7 909	C	0	43 254	Extra strong
	2	10	2.000	.108	5 100	6 560	6 062	C	7	55 607	Boiler tubes
	3	10	3.000	.112	3 220	4 860	3 967	C	1	52 957	Boiler tubes
	4	5	4.000	.135	3 640	4 070	3 840	C	2	56 978	Boiler tubes
	4	5	4.000	.136	3 720	4 040	3 914	B	1	57 440	Boiler tubes
						General average				52 225	
Steel — Seamless	2	10	2.000	.098	5 420	6 590	6 052	C	10	61 530	Boiler tubes
	3	10	3.000	.112	3 940	4 730	4 272	C	10	57 075	Boiler tubes
	4	6	4.000	.134	4 160	4 440	4 318	C	6	64 450	Boiler tubes
	4	4	4.000	.134	4 250	4 440	4 328	B	4	64 488	Boiler tubes
						General average				61 886	
Iron — Butt-welded	1 1/4	10	1.660	.136	2 880	6 290	5 283	C	3	32 126	Standard pipe
	1 1/4	10	1.660	.136	3 640	5 680	4 891	C	1	29 817	Standard pipe
	2	10	2.375	.156	2 930	4 250	3 687	C	2	28 051	Standard pipe
	1 1/4	10	1.660	.188	2 770	7 330	5 895	C	1	26 678	Extra strong
						General average				29 168	
Iron — Lap-welded	2	10	2.375	.152	2 400	3 940	3 213	C	1	25 122	Standard pipe
	2	10	2.375	.207	5 530	7 120	6 349	C	8	36 461	Extra strong
						General average				30 792	

The column marked "See note below" gives the number burst by failure of material not at weld.

C — Clavarino conditions, Fig. 115.

B — Birnie conditions, Fig. 114.

Strength of Weld of Commercial Tubes and Pipes

(Selected from Preceding Table of Bursting Tests.)

Size	Number burst in weld*	Average fiber stress by Barlow's formula	Class of material
		Steel — Butt-welded	
1/8	9	43 938	Standard pipe
1/4	9	37 777	Standard pipe
3/8	9	38 954	Standard pipe
1/2	10	58 163	Standard pipe
3/4	10	38 657	Standard pipe
1	10	35 085	Standard pipe
1 1/4	10	34 603	Standard pipe
1 1/4	14	45 643	Redrawn
1 1/2	10	33 031	Standard pipe
2	11	40 485	Standard pipe
2 1/2	10	37 351	Standard pipe
3	10	46 234	Standard pipe
1 1/4	10	48 922	Extra strong
2	10	45 935	Extra strong
2	10	41 347	Extra strong
2	10	40 023	XX strong
Gen. average		41 634	
		Steel — Lap-welded	
2	9	50 052	Standard pipe
2	10	47 889	Standard pipe
3	3	54 510	Standard pipe
4	9	51 019	Standard pipe
5	9	48 852	Standard pipe
6	10	47 026	Standard pipe
10	7	59 537	Standard pipe
2	10	43 254	Extra strong
2	3	56 933	Boiler tubes
3	9	51 980	Boiler tubes
4	7	57 521	Boiler tubes
Gen. average		51 688	
		Iron — Butt-welded	
1 1/4	7	31 136	Standard pipe
1 1/4	9	30 680	Standard pipe
2	8	27 323	Standard pipe
1 1/4	9	27 073	Extra strong
Gen. average		29 053	
		Iron — Lap-welded	
2	9	24 581	Standard pipe
2	2	34 340	Extra strong
Gen. average		29 461	

* These only are included in averages.

COLLAPSING PRESSURES

Until recently Sir Wm. Fairbairn's classic experiments on tubes subjected to external fluid pressure were the basis of the rules for collapse. The results of his tests on 40 odd tubes made up of riveted sheets soldered tight were transmitted to the Royal Society in 1858. As might be expected, conclusions and formulæ based on tests of such tubes could hardly be expected to apply to modern welded tubes with any approach to accuracy.

In view of the urgent need for experimental data of a highly reliable character on which a formula for collapsing strength could be based, Prof. R. T. Stewart, Dean of the Mechanical Engineering Department of the University of Pittsburgh, was authorized to plan and direct a series of experiments on full-sized tubing up to twenty feet in length, which work was carried out at the National Department of National Tube Company, at McKeesport, Pa., occupying the time of from one to six men continuously for a period of four years.

A full report of the details of these experiments will be found in Professor Stewart's paper presented before the American Society of Mechanical Engineers, May, 1906. The general scope of the tests and conclusions arrived at are described in an abstract of this paper as follows:

Series One. This series of tests was made on tubes that were 8⅝ inches outside diameter, for all of the different commercial thicknesses of wall, and in lengths of 2½, 5, 10, 15 and 20 feet between transverse joints tending to hold the tube to a circular form. The chief purpose of this series was to furnish data for determining which of the existing formulæ, if any, were applicable to modern lap-welded steel tubes, especially when used in comparatively long lengths, such as well casing, boiler tubes and long, plain flues.

Series Two. This series of tests was made on single lengths of 20 feet between end connections tending to hold the tube to a circular form. Seven sizes, from 3 to 10 inches outside diameter, and in all the commercial thicknesses obtainable, were tested. The chief purpose of these tests was to obtain, for commercial tubes, the manner in which the collapsing pressure of a tube is related to both the diameter and thickness of the wall.

Inapplicability of Previously Published Formulæ. Preparatory to entering upon the research all existing published formulæ that could be found were collected, and, after the completion of Series One, were tested as to their applicability to modern steel tubes. Among the formulæ thus tested were two each by Fairbairn, Unwin, Wehage and Clark, and one each by Nystrom, Grashof, Love, Belpaire, and the Board of Trade (British), all of which, with possibly two exceptions, appear to be based upon Fairbairn's experiments made upon tubes wholly unlike the modern product. Without exception, all of these formulæ, when thus tested, proved to be inapplicable to the wide range of conditions found

in modern practice. As an illustration of this, the very first tube tested in connection with this research failed under a pressure that exceeded by about 300 per cent. that calculated by means of Fairbairn's formula.

Results of Research. The principal conclusions to be drawn from the results of this research may be briefly stated as follows:

1. The length of tube, between transverse joints tending to hold it to a circular form, has no practical influence upon the collapsing pressure of a commercial lap-welded steel tube so long as this length is not less than about six times the diameter of the tube.

2. The formulæ, as based upon the research, for the collapsing pressures of modern lap-welded Bessemer steel tubes, are as follows:

$$P = 86\,670 \frac{t}{D} - 1386 \quad \text{(B)}$$

$$P = 50\,210\,000 \left(\frac{t}{D}\right)^3 \quad \text{(G)}$$

where P = collapsing pressure, pounds per square inch;
D = outside diameter of tube in inches;
t = thickness of wall in inches.

Formula (B) is for values of P greater than 581 pounds per square inch, or for values of $\frac{t}{D}$ greater than 0.023, while formula (G) is for values less than these.

These formulæ, while strictly correct for tubes that are 20 feet in length between transverse joints tending to hold them to a circular form, are at the same time substantially correct for all lengths greater than about six diameters. They have been tested for seven sizes, ranging from 3 to 10 inches outside diameter, in all obtainable thicknesses of wall, and are known to be correct for this range.

For the convenience of those who wish to apply these formulæ to practice, a table (pages 232–243) has been calculated, giving the collapsing pressures of tubes from 1 to 12¾ inches, outside diameter.

When applying these formulæ and tables to practice it should be remembered that a suitable factor of safety should be applied. The selection of a proper safety factor in any particular case should be left to the judgment of one who is quite familiar with the conditions under which the tube is to be used.

Ordinarily a safety factor of five is sufficient when the stresses due to actions other than a constant fluid pressure are more or less trivial. In case there are repeated fluctuations of the fluid pressure, vibration, shock, internal strain due to unequal heating, etc., then a larger safety factor of from six to twelve or more should be used, depending upon the severity of these actions.

3. The apparent fiber stress under which the different tubes failed varied from about 7000 pounds for the relatively thinnest to 35 000 pounds per square inch for the relatively thickest walls. Since the average yield point of the material was 37 000 and the tensile strength 58 000 pounds per square inch, it would appear that the strength of a

tube subjected to a fluid collapsing pressure is not dependent alone upon either the elastic limit or the ultimate strength of the material constituting it.

Marine law fixes the thickness of tubes that may be used subject to external or collapsing pressure, on Merchant (not Naval) Marine Vessels. The following is taken from the "Rules and Regulations prescribed by the Board of Supervising Inspectors of the Steamboat Inspection Service of the Department of Commerce and Labor, U. S. A., as amended January, 1912."

From page 32, paragraph 15: Working pressures and corresponding minimum thicknesses of wall for long, plain, lap-welded and seamless steel flues, 7 to 18 inches diameter, subjected to external pressure only, shall be determined by the following table and formula:

Outside diameter of flue	Working pressure in pounds per square inch						
	100	120	140	160	180	200	220
	Thickness of flue in inches. Safety factor, 5						
Inches							
7	.152	.160	.168	.177	.185	.193	.201
8	.174	.183	.193	.202	.211	.220	.229
9	.196	.206	.217	.227	.237	.248	.258
10	.218	.229	.241	.252	.264	.275	.287
11	.239	.252	.265	.277	.290	.303	.316
12	.261	.275	.289	.303	.317	.330	.344
13	.283	.298	.313	.328	.343	.358	.373
14	.301	.320	.337	.353	.369	.385	.402
15	.323	.343	.361	.378	.396	.413	.430
16	.344	.366	.385	.404	.422	.440	.459
17	.366	.389	.409	.429	.448	.468	.488
18	.387	.412	.433	.454	.475	.496	.516

Thicknesses in this table were calculated by formula:

$$T = \frac{[(F \times P) + 1386]\,D}{86\,670},$$

where D = outside diameter of flue in inches;
T = thickness of wall in inches;
P = working pressure in pounds per square inch;
F = factor of safety.

This formula is applicable to lengths greater than six diameters of flue, to working pressures greater than 100 pounds, to outside diameters of from 7 to 18 inches and to temperatures less than 650° F.

From page 34, paragraph 16: Lap-welded and seamless tubes, used in boilers whose construction was commenced after June 30, 1910, having a thickness of material according to their respective diameters, shall be allowed a working pressure as prescribed in the following table, provided they are deemed safe by the inspectors. Where heavier material is used, pressure may be allowed as prescribed in formula of paragraph 15, given above. Any length of tube is allowable.

Outside diameter	Thickness of material	Maximum pressure allowed
Inches	Inch	Pounds
2	.095	427
2¼	.095	380
2½	.109	392
2¾	.109	356
3	.109	327
3¼	.120	332
3½	.120	308
3¾	.120	282
4	.134	303
4½	.134	238
5	.148	235
6	.165	199

Comparison of Collapse and Column Formulæ. To connect these collapse tests with the known properties of material under compression, consider their relation to the supporting power of columns as pointed out in 1876 by Prof. W. C. Unwin.* Consider a short portion of the pipe, say, one inch long. The thickness bears a relation to the radius of gyration and the circumference a relation to the length of a column whose ends are "fixed." Expressed in symbols, these relations are

$$\frac{D}{t} = .1838\frac{L}{R} + 1.$$

By this rule can be computed the value of $\frac{t}{D}$ that corresponds to $\frac{L}{R}$ of any column tested. The pressure (P) corresponding to the supporting power $\frac{P_1}{A}$ of a column is obtained by putting $\frac{P_1}{A} = S$ in the rule $\frac{S}{P} = \frac{D}{2t}$. By these rules a diagram, Fig. 118, has been constructed from tests of columns. The diagram is plotted to show the relation between collapsing pressure and ratio of thickness to diameter. It is evident from this diagram that collapsing pressure can be calculated either from tests of columns or directly from tests of collapse.

The heavy full line is by formulæ (B) and (G), page 228. The solid dots are from Christie's tests on fixed end columns. The circles are from Watertown tests on pipe columns. The dot and dash line is from Christie's tests of columns of steel having 0.12 per cent. Carbon and the dotted line from Christie's tests of columns of steel having 0.36 per cent. Carbon. The last two indicate what increase in collapsing pressure may be expected from the use of high strength steel.

The change in the direction of the lines (from column tests), which starts at about $\frac{t}{D} = 0.10$, indicates that the straight line formula for

* Proc. Ins. Civ. Engrs., Vol. 46, p. 225.

collapse should not be extrapolated far outside the range of experiments on which it was based. This diagram indicates the remarkable confirmation that column tests lend to the results of these collapse tests.

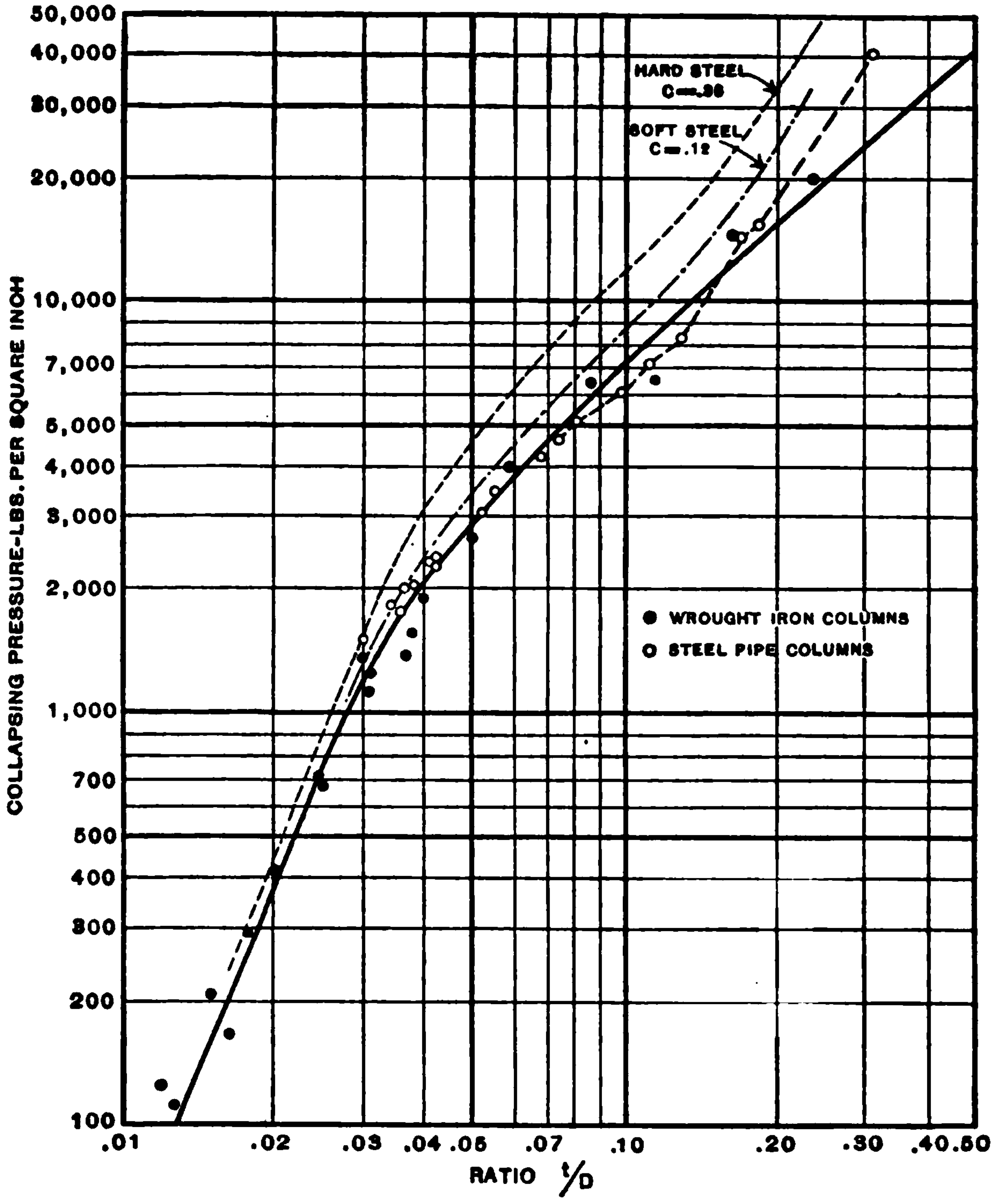


Fig. 118

Prof. W. E. Lilly,* proceeding by a process of reasoning similar to that used in obtaining a column formula, has derived the following formula for collapse, $P = \dfrac{80\,000}{\dfrac{D}{t} + \dfrac{1}{1000}\left(\dfrac{D}{t}\right)^3}$, in which the constants are empirical and based on Professor Stewart's collapse tests. This formula, being derived by the same process that is used to obtain a column formula, gives another connection between the supporting power of columns and the collapse of tubes.

* Irish Ins. of Civ. Engrs.

Collapsing Pressures — Pounds per Square Inch

(Based on Professor Stewart's Formulæ B and G.)

Formulæ

$P = 86\,670\,t/D - 1386$. . . . (B). $P = 50\,210\,000\,(t/D)^3$. . . . (G).

Where P = collapsing pressure in pounds per square inch;

D = outside diameter of tube in inches; t = thickness of wall in inches.

Thickness	Outside diameter — Inches							
	1.000	1.050	1.125	1.250	1.315	1.375	1.500	1.660
.01								
.02	402	347	282	206				
.03	1 214	1 090	925	694	596	521	402	
.04	2 081	1 916	1 696	1 387	1 250	1 135	925	
.05	2 948	2 741	2 466	2 081	1 909	1 766	1 503	
.06	3 814	3 567	3 236	2 774	2 568	2 396	2 081	1 747
.07	4 681	4 392	4 007	3 468	3 228	3 026	2 659	2 269
.08	5 548	5 217	4 777	4 161	3 887	3 657	3 236	2 791
.09	6 414	6 043	5 548	4 854	4 546	4 287	3 814	3 313
.10	7 281	6 868	6 318	5 548	5 205	4 917	4 392	3 835
.11	8 148	7 694	7 088	6 241	5 864	5 548	4 970	4 357
.12	9 014	8 519	7 859	6 934	6 523	6 178	5 548	4 879
.13	9 881	9 345	8 629	7 628	7 182	6 808	6 125	5 401
.14	10 748	10 170	9 400	8 321	7 841	7 439	6 703	5 923
.15	11 615	10 995	10 170	9 014	8 500	8 069	7 281	6 446
.16	12 481	11 821	10 940	9 708	9 159	8 699	7 859	6 968
.17	13 348	12 646	11 711	10 401	9 818	9 330	8 437	7 490
.18	14 215	13 472	12 481	11 094	10 478	9 960	9 014	8 012
.19	15 081	14 297	13 252	11 788	11 137	10 590	9 592	8 534
.20	15 948	15 123	14 022	12 481	11 796	11 221	10 170	9 056
.21	16 815	15 948	14 792	13 175	12 455	11 851	10 748	9 578
.22	17 681	16 773	15 563	13 868	13 114	12 481	11 326	10 100
.23	18 548	17 599	16 333	14 561	13 773	13 112	11 903	10 622
.24	19 415	18 424	17 104	15 255	14 432	13 742	12 481	11 145
.25	20 282	19 250	17 874	15 948	15 091	14 372	13 059	11 667
.26	21 148	20 075	18 644	16 641	15 750	15 003	13 637	12 189
.27	22 015	20 901	19 415	17 335	16 409	15 633	14 215	12 711
.28	22 882	21 726	20 185	18 028	17 068	16 263	14 792	13 233
.29	23 748	22 551	20 956	18 721	17 728	16 893	15 370	13 755
.30	24 615	23 377	21 726	19 415	18 387	17 524	15 948	14 277
.31	....	24 202	22 496	20 108	19 046	18 154	16 526	14 799
.32	....	....	....	20 802	19 705	18 784	17 104	15 321
.33	....	....	....	21 495	20 364	19 415	17 681	15 844
.34	....	....	....	22 188	21 023	20 045	18 259	16 366
.35	....	....	....	22 882	21 682	20 675	18 837	16 888
.36	....	....	....	23 575	22 341	21 306	19 415	17 410
.37	....	....	....	24 268	23 000	21 936	19 993	17 932
.38	....	....	....	....	....	....	....	18 454
.39	....	....	....	....	....	....	....	18 976
.40	....	....	....	....	....	....	....	....
.41	....	....	....	....	....	....	....	....
.42	....	....	....	....	....	....	....	....
.43	....	....	....	....	....	....	....	....
.44	....	....	....	....	....	....	....	....
.45	....	....	....	....	....	....	....	....
.46	....	....	....	....	....	....	....	....
.47	....	....	....	....	....	....	....	....
.48	....	....	....	....	....	....	....	....
.49	....	....	....	....	....	....	....	....

Collapsing Pressures — Pounds per Square Inch (Continued)
(Based on Professor Stewart's Formulæ B and G.)

Formulæ

$P = 86\,670\, t/D - 1386 \ldots .(B).$ $P = 50\,210\,000\,(t/D)^3 \ldots .(G).$

Where P = collapsing pressure in pounds per square inch;
D = outside diameter of tube in inches; t = thickness of wall in inches.

Thickness	Outside diameter — Inches						
	1.750	1.875	1.900	2.000	2.250	2.375	2.500
.01							
.02							
.03							
.04							
.05							
.06	1 586	1 387	1 351	1 214	925	804	694
.07	2 081	1 850	1 807	1 647	1 310	1 169	1 041
.08	2 576	2 312	2 263	2 081	1 696	1 533	1 387
.09	3 071	2 774	2 719	2 514	2 081	1 898	1 734
.10	3 567	3 236	3 176	2 948	2 466	2 263	2 081
.11	4 062	3 699	3 632	3 381	2 851	2 628	2 427
.12	4 557	4 161	4 088	3 814	3 236	2 993	2 774
.13	5 052	4 623	4 544	4 248	3 622	3 358	3 121
.14	5 548	5 085	5 000	4 681	4 007	3 723	3 468
.15	6 043	5 548	5 456	5 114	4 392	4 088	3 814
.16	6 538	6 010	5 913	5 548	4 777	4 453	4 161
.17	7 033	6 472	6 369	5 981	5 162	4 818	4 508
.18	7 529	6 934	6 825	6 414	5 548	5 183	4 854
.19	8 024	7 397	7 281	6 848	5 933	5 548	5 201
.20	8 519	7 859	7 737	7 281	6 318	5 913	5 548
.21	9 014	8 321	8 193	7 714	6 703	6 277	5 894
.22	9 510	8 783	8 649	8 148	7 088	6 642	6 241
.23	10 005	9 246	9 106	8 581	7 474	7 007	6 588
.24	10 500	9 708	9 562	9 014	7 859	7 372	6 934
.25	10 995	10 170	10 018	9 448	8 244	7 737	7 281
.26	11 491	10 632	10 474	9 881	8 629	8 102	7 628
.27	11 986	11 094	10 930	10 314	9 014	8 467	7 974
.28	12 481	11 557	11 386	10 748	9 400	8 832	8 321
.29	12 976	12 019	11 843	11 181	9 785	9 197	8 668
.30	13 472	12 481	12 299	11 615	10 170	9 562	9 014
.31	13 967	12 943	12 755	12 048	10 555	9 927	9 361
.32	14 462	13 406	13 211	12 481	10 940	10 292	9 708
.33	14 957	13 868	13 667	12 915	11 326	10 657	10 054
.34	15 453	14 330	14 123	13 348	11 711	11 021	10 401
.35	15 948	14 792	14 580	13 781	12 096	11 386	10 748
.36	16 443	15 255	15 036	14 215	12 481	11 751	11 094
.37	16 939	15 717	15 492	14 648	12 866	12 116	11 441
.38	17 434	16 179	15 948	15 081	13 252	12 481	11 788
.39	17 929	16 641	16 404	15 515	13 637	12 846	12 135
.40	18 424	17 104	16 860	15 948	14 022	13 211	12 481
.41	....	....	....	16 381	14 407	13 576	12 828
.42	....	....	....	16 815	14 792	13 941	13 175
.43	....	....	....	17 248	15 178	14 306	13 521
.44	....	....	....	17 681	15 563	14 671	13 868
.45	....	....	....	....	....	15 036	14 215
.46	....	....	....	....	....	15 401	14 561
.47	....	....	....	....	....	....	....
.48	....	....	....	....	....	....	....
.49	....	....	....	....	....	....	....

Collapsing Pressures — Pounds per Square Inch (Continued)
(Based on Professor Stewart's Formulæ B and G.)

Formulæ

$P = 86\,670\,t/D - 1386$ . . . . (B). $P = 50\,210\,000\,(t/D)^3$ . . . . (G).

Where P = collapsing pressure in pounds per square inch;
D = outside diameter of tube in inches; t = thickness of wall in inches.

Thickness	Outside diameter — Inches						
	2.750	2.875	3.000	3.250	3.500	3.750	4.000
.01							
.02							
.03							
.04							
.05							
.06	521						
.07	820						
.08	1 135						
.09	1 450	1 327	1 214	1 014	843		
.10	1 766	1 629	1 503	1 281	1 090		
.11	2 081	1 930	1 792	1 547	1 338		
.12	2 396	2 232	2 081	1 814	1 586	1387	1214
.13	2 711	2 533	2 370	2 081	1 833	1619	1431
.14	3 026	2 834	2 659	2 347	2 081	1850	1647
.15	3 341	3 136	2 948	2 614	2 328	2081	1864
.16	3 657	3 437	3 236	2 881	2 576	2312	2081
.17	3 972	3 739	3 525	3 148	2 824	2543	2297
.18	4 287	4 040	3 814	3 414	3 071	2774	2514
.19	4 602	4 342	4 103	3 681	3 319	3005	2731
.20	4 917	4 643	4 392	3 947	3 567	3236	2948
.21	5 232	4 945	4 681	4 214	3 814	3468	3164
.22	5 548	5 246	4 970	4 481	4 062	3699	3381
.23	5 863	5 548	5 259	4 748	4 309	3930	3598
.24	6 178	5 849	5 548	5 014	4 557	4161	3814
.25	6 493	6 151	5 836	5 281	4 805	4392	4031
.26	6 808	6 452	6 125	5 548	5 052	4623	4248
.27	7 123	6 753	6 414	5 814	5 300	4854	4464
.28	7 439	7 055	6 703	6 081	5 548	5085	4681
.29	7 754	7 356	6 992	6 348	5 795	5316	4898
.30	8 069	7 658	7 281	6 614	6 043	5548	5114
.31	8 384	7 959	7 570	6 881	6 290	5779	5331
.32	8 699	8 261	7 859	7 148	6 538	6010	5548
.33	9 014	8 562	8 148	7 414	6 786	6241	5764
.34	9 330	8 864	8 437	7 681	7 033	6472	5981
.35	9 645	9 165	8 726	7 948	7 281	6703	6198
.36	9 960	9 467	9 014	8 214	7 529	6934	6414
.37	10 275	9 768	9 303	8 481	7 776	7165	6631
.38	10 590	10 070	9 592	8 748	8 024	7397	6848
.39	10 905	10 371	9 881	9 014	8 272	7628	7064
.40	11 221	10 672	10 170	9 281	8 519	7759	7281
.41	11 536	10 974	10 459	9 548	8 767	8090	7498
.42	11 851	11 275	10 748	9 814	9 014	8321	7714
.43	12 166	11 577	11 037	10 081	9 262	8552	7931
.44	12 481	11 878	11 326	10 348	9 510	8783	8148
.45	12 796	12 180	11 615	10 615	9 757	9014	8364
.46	13 112	12 481	11 903	10 881	10 005	9246	8581
.47	....	12 783	12 192	11 148	10 253	9477	8798
.48	....	13 084	12 481	11 414	10 500	9708	9014
.49	....	13 386	12 770	11 681	10 748	9939	9231

Collapsing Pressures — Pounds per Square Inch (Continued)

(Based on Professor Stewart's Formulæ B and G.)

Formulæ

$P = 86\,670\,t/D - 1386$. . . . (B). $P = 50\,210\,000\,(t/D)^3$. . . . (G).

Where P = collapsing pressure in pounds per square inch;

D = outside diameter of tube in inches; t = thickness of wall in inches.

Thickness	Outside diameter — Inches						
	2.750	2.875	3.000	3.250	3.500	3.750	4.000
.50	....	13 687	13 059	11 948	10 995	10 170	9 448
.51	....	13 988	13 348	12 215	11 243	10 401	9 664
.52	....	14 290	13 637	12 481	11 491	10 632	9 881
.53	....	14 591	13 926	12 748	11 738	10 863	10 098
.54	....	14 893	14 215	13 015	11 986	11 094	10 314
.55	....	15 194	14 503	13 281	12 234	11 326	10 531
.56	....	15 496	14 792	13 548	12 481	11 557	10 748
.57	....	....	....	....	12 729	11 788	10 964
.58	....	....	....	....	12 976	12 019	11 181
.59	....	....	....	....	13 224	12 250	11 398
.60	....	....	....	....	13 472	12 481	11 615
.61	....	....	....	....	....	12 712	11 831
.62	....	....	....	....	....	12 943	12 048
.63	....	....	....	....	....	13 175	12 265
.64	....	....	....	....	....	13 406	12 481
.65	....	....	....	....	....	....	....
.66	....	....	....	....	....	....	....
.67	....	....	....	....	....	....	....
.68	....	....	....	....	....	....	....
.69	....	....	....	....	....	....	....
.70	....	....	....	....	....	....	....
.71	....	....	....	....	....	....	....
.72	....	....	....	....	....	....	....
.73	....	....	....	....	....	....	....
.74	....	....	....	....	....	....	....
.75	....	....	....	....	....	....	....
.76	....	....	....	....	....	....	....
.77	....	....	....	....	....	....	....
.78	....	....	....	....	....	....	....
.79	....	....	....	....	....	....	....
.80	....	....	....	....	....	....	....
.81	....	....	....	....	....	....	....
.82	....	....	....	....	....	....	....
.83	....	....	....	....	....	....	....
.84	....	....	....	....	....	....	....
.85	....	....	....	....	....	....	....
.86	....	....	....	....	....	....	....
.87	....	....	....	....	....	....	....
.88	....	....	....	....	....	....	....
.89	....	....	....	....	....	....	....
.90	....	....	....	....	....	....	....
.91	....	....	....	....	....	....	....
.92	....	....	....	....	....	....	....
.93	....	....	....	....	....	....	....
.94	....	....	....	....	....	....	....
.95	....	....	....	....	....	....	....
.96	....	....	....	....	....	....	....
.97	....	....	....	....	....	....	....
.98	....	....	....	....	....	....	....
.99	....	....	....	....	....	....	....
1.00	....	....	....	....	....	....	....

Collapsing Pressures — Pounds per Square Inch (Continued)

(Based on Professor Stewart's Formulæ B and G.)

Formulæ

$P = 86\,670\,t/D - 1386$....(B). $P = 50\,210\,000\,(t/D)^3$....(G).

Where P = collapsing pressure in pounds per square inch;

D = outside diameter of tube in inches; t = thickness of wall in inches.

Thickness	Outside diameter — Inches						
	4.250	4.500	4.750	5.000	5.250	5.500	5.563
.01							
.02							
.03							
.04							
.05							
.06							
.07							
.08							
.09							
.10							
.11							
.12	1061	925					
.13	1265	1118	986	867	760	663	
.14	1469	1310	1169	1041	925	820	795
.15	1673	1503	1351	1214	1090	978	951
.16	1877	1696	1533	1387	1255	1135	1107
.17	2081	1888	1716	1561	1420	1293	1263
.18	2285	2081	1898	1734	1586	1450	1418
.19	2489	2273	2081	1907	1751	1608	1574
.20	2693	2466	2263	2081	1916	1766	1730
.21	2897	2659	2446	2254	2081	1923	1886
.22	3100	2851	2628	2427	2246	2081	2042
.23	3304	3044	2811	2601	2411	2238	2197
.24	3508	3236	2993	2774	2576	2396	2353
.25	3712	3429	3176	2948	2741	2554	2509
.26	3916	3622	3358	3121	2906	2711	2665
.27	4120	3814	3540	3294	3071	2869	2821
.28	4324	4007	3723	3468	3236	3026	2976
.29	4528	4199	3905	3641	3401	3184	3132
.30	4732	4392	4088	3814	3567	3341	3288
.31	4936	4585	4270	3988	3732	3499	3444
.32	5140	4777	4453	4161	3897	3657	3600
.33	5344	4970	4635	4334	4062	3814	3755
.34	5548	5162	4818	4508	4227	3972	3911
.35	5752	5355	5000	4681	4392	4129	4067
.36	5955	5548	5183	4854	4557	4287	4223
.37	6159	5740	5365	5028	4722	4445	4378
.38	6363	5933	5548	5201	4887	4602	4534
.39	6567	6125	5730	5374	5052	4760	4690
.40	6771	6318	5913	5548	5217	4917	4846
.41	6975	6511	6095	5721	5383	5075	5002
.42	7179	6703	6277	5894	5548	5232	5157
.43	7383	6896	6460	6068	5713	5390	5313
.44	7587	7088	6642	6241	5878	5548	5469
.45	7791	7281	6825	6414	6043	5705	5625
.46	7995	7474	7007	6588	6208	5863	5781
.47	8199	7666	7190	6761	6373	6020	5936
.48	8403	7859	7372	6934	6538	6178	6092
.49	8607	8051	7555	7108	6703	6336	6248

Collapsing Pressures — Pounds per Square Inch (Continued)
(Based on Professor Stewart's Formulæ B and G.)

Formulæ

$P = 86\,670\,t/D - 1386$ . . . . (B). $P = 50\,210\,000\,(t/D)^3$ . . . . (G).
Where P = collapsing pressure in pounds per square inch;
D = outside diameter of tube in inches; t = thickness of wall in inches.

Thickness	Outside diameter — Inches						
	4.250	4.500	4.750	5.000	5.250	5.500	5.563
.50	8 810	8 244	7 737	7 281	6 868	6493	6 404
.51	9 014	8 437	7 920	7 454	7 033	6651	6 560
.52	9 218	8 629	8 102	7 628	7 198	6808	6 715
.53	9 422	8 822	8 285	7 801	7 364	6966	6 871
.54	9 626	9 014	8 467	7 974	7 529	7123	7 027
.55	9 830	9 207	8 649	8 148	7 694	7281	7 183
.56	10 034	9 400	8 832	8 321	7 859	7439	7 339
.57	10 238	9 592	9 014	8 494	8 024	7596	7 494
.58	10 442	9 785	9 197	8 668	8 189	7754	7 650
.59	10 646	9 977	9 379	8 841	8 354	7911	7 806
.60	10 850	10 170	9 562	9 014	8 519	8069	7 962
.61	11 054	10 363	9 744	9 188	8 684	8226	8 118
.62	11 258	10 555	9 927	9 361	8 849	8384	8 273
.63	11 462	10 748	10 109	9 534	9 014	8542	8 429
.64	11 665	10 940	10 292	9 708	9 179	8699	8 585
.65	....	11 133	10 474	9 881	9 345	8857	8 741
.66	....	11 326	10 657	10 054	9 510	9014	8 897
.67	....	11 518	10 839	10 228	9 675	9172	9 052
.68	....	11 711	11 022	10 401	9 840	9330	9 208
.69	....	....	....	10 574	10 005	9487	9 364
.70	....	....	....	10 748	10 170	9645	9 520
.71	....	....	....	10 921	10 335	9802	9 676
.72	....	....	....	....	....	....	9 831
.73	....	....	....	....	....	....	9 987
.74	....	....	....	....	....	....	10 143
.75	....	....	....	....	....	....	10 299
.76	....	....	....	....	....	....	....
.77	....	....	....	....	....	....	....
.78	....	....	....	....	....	....	....
.79	....	....	....	....	....	....	....
.80	....	....	....	....	....	....	....
.81	....	....	....	....	....	....	....
.82	....	....	....	....	....	....	....
.83	....	....	....	....	....	....	....
.84	....	....	....	....	....	....	....
.85	....	....	....	....	....	....	....
.86	....	....	....	....	....	....	....
.87	....	....	....	....	....	....	....
.88	....	....	....	....	....	....	....
.89	....	....	....	....	....	....	....
.90	....	....	....	....	....	....	....
.91	....	....	....	....	....	....	....
.92	....	....	....	....	....	....	....
.93	....	....	....	....	....	....	....
.94	....	....	....	....	....	....	....
.95	....	....	....	....	....	....	....
.96	....	....	....	....	....	....	....
.97	....	....	....	....	....	....	....
.98	....	....	....	....	....	....	....
.99	....	....	....	....	....	....	....
1.00	....	....	....	....	....	....	....

Collapsing Pressures — Pounds per Square Inch (Continued)
(Based on Professor Stewart's Formulæ B and G.)

Formulæ

$P = 86\,670\,t/D - 1386$ . . . . (B). $P = 50\,210\,000\,(t/D)^3$ . . . . (G).

Where P = collapsing pressure in pounds per square inch;
D = outside diameter of tube in inches; t = thickness of wall in inches.

Thickness	Outside diameter — Inches						
	8.500	8.625	9.000	9.500	9.625	10.000	10.500
.01							
.02							
.03							
.04							
.05							
.06							
.07							
.08							
.09							
.10							
.11							
.12							
.13							
.14							
.15	276						
.16	335	320	282	240	230		
.17	402	385	338	288	277	247	213
.18	477	456	402	341	328	293	253
.19	561	537	472	402	386	344	297
.20	653	624	551	468	450	402	347
.21	755	724	636	542	521	465	402
.22	857	825	733	621	600	535	462
.23	959	925	829	712	685	611	528
.24	1061	1026	925	804	775	694	600
.25	1163	1126	1022	895	865	781	678
.26	1265	1227	1118	986	955	867	760
.27	1367	1327	1214	1077	1045	954	843
.28	1469	1428	1310	1168	1135	1041	925
.29	1571	1528	1407	1260	1225	1127	1008
.30	1673	1629	1503	1351	1315	1214	1090
.31	1775	1729	1599	1442	1405	1301	1173
.32	1877	1830	1696	1533	1495	1387	1255
.33	1979	1930	1792	1625	1586	1474	1338
.34	2081	2031	1888	1716	1676	1561	1420
.35	2183	2131	1985	1807	1766	1647	1503
.36	2285	2232	2081	1898	1856	1734	1586
.37	2387	2332	2177	1990	1946	1821	1668
.38	2489	2433	2273	2081	2036	1907	1751
.39	2591	2533	2370	2172	2126	1994	1833
.40	2693	2633	2466	2263	2216	2081	1916
.41	2795	2734	2562	2355	2306	2167	1998
.42	2897	2834	2659	2446	2396	2254	2081
.43	2998	2935	2755	2537	2486	2341	2163
.44	3100	3035	2851	2628	2576	2427	2246
.45	3202	3136	2948	2719	2666	2514	2328
.46	3304	3236	3044	2811	2756	2601	2411
.47	3406	3337	3140	2902	2846	2687	2494
.48	3508	3437	3236	2993	2936	2774	2576
.49	3610	3538	3333	3084	3026	2861	2659

Collapsing Pressures — Pounds per Square Inch (Continued)
(Based on Professor Stewart's Formulæ B and G.)

Formulæ

$P = 86\,670\, t/D - 1386 \ldots.(B)$. $\quad P = 50\,210\,000\,(t/D)^3 \ldots.(G)$.

Where P = collapsing pressure in pounds per square inch;
D = outside diameter of tube in inches; t = thickness of wall in inches.

Thickness	Outside diameter — Inches						
	8.500	8.625	9.000	9.500	9.625	10.000	10.500
.50	3712	3638	3429	3176	3116	2948	2741
.51	3814	3739	3525	3267	3206	3034	2824
.52	3916	3839	3622	3358	3296	3121	2906
.53	4018	3940	3718	3449	3386	3208	2989
.54	4120	4040	3814	3541	3477	3294	3071
.55	4222	4141	3910	3632	3567	3381	3154
.56	4324	4241	4007	3723	3657	3468	3236
.57	4426	4342	4103	3814	3747	3554	3319
.58	4528	4442	4199	3905	3837	3641	3401
.59	4630	4543	4296	3997	3927	3728	3484
.60	4732	4643	4392	4088	4017	3814	3567
.61	4834	4744	4488	4179	4107	3901	3649
.62	4936	4844	4585	4270	4197	3988	3732
.63	5038	4945	4681	4362	4287	4074	3814
.64	5140	5045	4777	4453	4377	4161	3897
.65	5242	5146	4873	4544	4467	4248	3979
.66	5344	5246	4970	4635	4557	4334	4062
.67	5446	5347	5066	4727	4647	4421	4144
.68	5548	5447	5162	4818	4737	4508	4227
.69	5650	5548	5259	4909	4827	4594	4309
.70	5752	5648	5355	5000	4917	4681	4392
.71	5853	5749	5451	5091	5007	4768	4475
.72	5955	5849	5548	5183	5097	4854	4557
.73	6057	5950	5644	5274	5187	4941	4640
.74	6159	6050	5740	5365	5277	5028	4722
.75	6261	6151	5836	5456	5368	5114	4805
.76	6363	6251	5933	5548	5458	5201	4887
.77	6465	6351	6029	5639	5548	5288	4970
.78	6567	6452	6125	5730	5638	5374	5052
.79	6669	6552	6222	5821	5728	5461	5135
.80	6771	6653	6318	5913	5818	5548	5217
.81	6873	6753	6414	6004	5908	5634	5300
.82	6975	6854	6511	6095	5998	5721	5383
.83	7077	6954	6607	6186	6088	5808	5465
.84	7179	7055	6703	6277	6178	5894	5548
.85	7281	7155	6799	6369	6268	5981	5630
.86	7383	7256	6896	6460	6358	6068	5713
.87	7485	7356	6992	6551	6448	6154	5795
.88	7587	7457	7088	6642	6538	6241	5878
.89	....	....	....	6734	6628	6328	5960
.90	....	....	....	6825	6718	6414	6043
.91	....	....	....	6916	6808	6501	6125
.92	....	....	....	7007	6898	6588	6208
.93	....	....	....	7099	6988	6674	6290
.94	....	....	....	7190	7078	6761	6373
.95	....	....	....	7281	7168	6848	6456
.96	....	....	....	7372	7258	6934	6538
.97	....	....	....	7464	7349	7021	6621
.98	....	....	....	7555	7439	7108	6703
.99	....	....	....	7646	7529	7194	6786
1.00	....	....	....	7737	7619	7281	6868

Collapsing Pressures — Pounds per Square Inch (Continued)
(Based on Professor Stewart's Formulæ B and G.)

Formulæ

$P = 86\,670\,t/D - 1386 \ldots.$ (B). $P = 50\,210\,000\,(t/D)^3 \ldots.$ (G).

Where P = collapsing pressure in pounds per square inch;
D = outside diameter of tube in inches; t = thickness of wall in inches.

Thick-ness	Outside diameter — Inches						
	10.750	11.000	11.500	11.750	12.000	12.500	12.750
.01							
.02							
.03							
.04							
.05							
.06							
.07							
.08							
.09							
.10							
.11							
.12							
.13							
.14							
.15							
.16							
.17							
.18	236	220	192	180	170	150	141
.19	277	259	226	212	199	176	166
.20	323	302	264	248	232	206	194
.21	374	349	306	287	269	238	224
.22	430	402	351	329	309	274	258
.23	492	459	402	377	353	313	295
.24	559	522	456	428	402	355	335
.25	630	589	516	484	454	402	379
.26	710	663	580	544	511	452	426
.27	791	741	649	609	572	506	477
.28	871	820	724	679	636	564	532
.29	952	899	800	753	709	625	591
.30	1033	978	875	827	781	694	653
.31	1113	1057	950	901	853	763	721
.32	1194	1135	1026	974	925	833	789
.33	1275	1214	1101	1048	997	902	857
.34	1355	1293	1176	1122	1070	971	925
.35	1436	1372	1252	1196	1142	1041	993
.36	1516	1450	1327	1269	1214	1110	1061
.37	1597	1529	1403	1343	1286	1179	1129
.38	1678	1608	1478	1417	1359	1249	1197
.39	1758	1687	1553	1491	1431	1318	1265
.40	1839	1766	1629	1564	1503	1387	1333
.41	1920	1844	1704	1638	1575	1457	1401
.42	2000	1923	1779	1712	1647	1526	1469
.43	2081	2002	1855	1786	1720	1595	1537
.44	2161	2081	1930	1860	1792	1665	1605
.45	2242	2160	2205	1933	1864	1734	1673
.46	2323	2238	2081	2007	1936	1803	1741
.47	2403	2317	2156	2081	2009	1873	1809
.48	2484	2396	2232	2155	2081	1942	1877
.49	2565	2475	2307	2228	2153	2011	1945

Collapsing Pressures — Pounds per Square Inch (Concluded)
(Based on Professor Stewart's Formulæ B and G.)

Formulæ

$P = 86\,670\,t/D - 1386$. . . . (B). $P = 50\,210\,000\,(t/D)^3$. . . . (G).

Where P = collapsing pressure in pounds per square inch;
D = outside diameter of tube in inches; t = thickness of wall in inches.

Thickness	Outside diameter — Inches						
	10.750	11.000	11.500	11.750	12.000	12.500	12.750
.50	2645	2554	2382	2302	2225	2081	2013
.51	2726	2632	2458	2376	2297	2150	2081
.52	2806	2711	2533	2450	2370	2219	2149
.53	2887	2790	2608	2523	2442	2289	2217
.54	2968	2869	2684	2597	2514	2358	2285
.55	3048	2947	2759	2671	2586	2427	2353
.56	3129	3026	2834	2745	2659	2497	2421
.57	3210	3105	2910	2818	2731	2566	2489
.58	3290	3184	2985	2892	2803	2635	2557
.59	3371	3263	3061	2966	2875	2705	2625
.60	3451	3341	3136	3040	2948	2774	2693
.61	3532	3420	3211	3113	3020	2843	2761
.62	3613	3499	3287	3187	3092	2913	2829
.63	3693	3578	3362	3261	3164	2982	2897
.64	3774	3657	3437	3335	3236	3052	2964
.65	3855	3735	3513	3409	3309	3121	3032
.66	3935	3814	3588	3482	3381	3190	3100
.67	4016	3893	3663	3556	3453	3260	3168
.68	4096	3972	3739	3630	3525	3329	3236
.69	4177	4051	3814	3704	3598	3398	3304
.70	4258	4129	3890	3777	3670	3468	3372
.71	4338	4208	3965	3851	3742	3537	3440
.72	4419	4287	4040	3925	3814	3606	3508
.73	4499	4366	4116	3999	3886	3676	3576
.74	4580	4445	4191	4072	3959	3745	3644
.75	4661	4523	4266	4146	4031	3814	3712
.76	4741	4602	4342	4220	4103	3884	3780
.77	4822	4681	4417	4294	4175	3953	3848
.78	4903	4760	4492	4367	4248	4022	3916
.79	4983	4838	4568	4441	4320	4092	3984
.80	5064	4917	4643	4515	4392	4161	4052
.81	5144	4996	4719	4589	4464	4230	4120
.82	5225	5075	4794	4662	4536	4300	4188
.83	5306	5154	4869	4736	4609	4369	4256
.84	5386	5232	4945	4810	4681	4438	4324
.85	5467	5311	5020	4884	4753	4508	4392
.86	5548	5390	5095	4958	4825	4577	4460
.87	5628	5469	5171	5031	4898	4646	4528
.88	5709	5548	5246	5105	4970	4716	4596
.89	5789	5626	5322	5179	5042	4785	4664
.90	5870	5705	5397	5253	5114	4854	4732
.91	5951	5784	5472	5326	5186	4924	4800
.92	6031	5863	5548	5400	5259	4993	4868
.93	6112	5942	5623	5474	5331	5062	4936
.94	6193	6020	5698	5548	5403	5132	5004
.95	6273	6099	5774	5621	5475	5201	5072
.96	6354	6178	5849	5695	5548	5270	5140
.97	6434	6257	5924	5769	5620	5340	5208
.98	6515	6336	6000	5843	5692	5409	5276
.99	6596	6414	6075	5916	5764	5478	5344
1.00	6676	6493	6151	5990	5836	5548	5412

PIPE COLUMNS

Those parts of a structure that resist thrust or compressive stress are known as columns or struts. Except when comparatively quite short, columns and struts tend to fail by lateral bending or buckling. While apparently similar in this respect to beams, the real stresses in a loaded column are, however, of such an obscure nature that no satisfactory theoretical formula has yet been produced for columns of the proportions commonly used in practice. The only really useful formulæ for columns and struts are those based directly upon experimental data.

Radius of Gyration. The radius of gyration is the property of the cross-section of a column that determines its strength. The relation of the radius of gyration, R, to the moment of inertia, I, and area of cross-section, A, is such that it equals the square root of the quotient resulting from dividing the former by the latter, or $R = \sqrt{I \div A}$.

Slenderness Ratio. The strength of a column or strut is most easily expressed in terms of its slenderness ratio, which is the length divided by the least radius of gyration, $\frac{L}{R}$, both being stated in inches.

Strength of Columns. The strength of a column or strut depends (1) upon the manner in which the ends are connected to the rest of the structure, whether fixed in direction, hinged, etc., and upon the placing of the loading, whether axial or eccentric; (2) upon the slenderness ratio, $\frac{L}{R}$; (3) upon the area of cross-section, A; and (4) upon the physical properties of the material.

Tables of Safe Loads for Pipe Columns. The tables, pages 245 to 249, give the safe loads in tons of 2000 pounds for Standard, Extra Strong, and Double Extra Strong Pipe, computed by the formulæ of the New York and Chicago Building Laws.

According to the New York Building Code, the allowable compressive stress per square inch for steel columns with flat ends is given by the formula $S = 15\,200 - 58\frac{L}{R}$, where L is the length of the column and R is the least radius of gyration, both in inches. It further states that no column shall be used whose unsupported length is greater than 120 times its least radius of gyration.

According to the Chicago Building Ordinances the allowable compressive stress per square inch for steel columns shall be determined by the formula $S = 16\,000 - 70\frac{L}{R}$, with a maximum allowable stress of 14 000 pounds per square inch. The length of column is limited to 120 times the least radius of gyration, except in the case of struts for wind bracing, in which case the limit is 150 times the least radius of gyration.

Standard Pipe Columns

(Loads in tons of 2000 pounds, based on New York Building Code.)

$$S = 15\,200 - 58\ L/R.$$

S = allowable compressive stress for steel, pounds per square inch;
L = length of column in inches;
R = least radius of gyration in inches.

Length, feet	Size of pipe								
	2	2½	3	3½	4	4½	5	6	7
	Thickness								
	.154	.203	.216	.226	.237	.247	.258	.280	.301
40	......	......	......	......	......	......	......	......	......
36	......	......	......	......	......	......	......	......	19.16
33	......	......	......	......	......	......	......	13.87	21.95
30	......	......	......	......	......	......	......	16.47	24.74
27	......	......	......	......	......	......	11.16	19.06	27.53
24	......	......	......	......	......	9.72	13.55	21.66	30.32
22	......	......	......	......	8.02	11.25	15.15	23.39	32.18
20	......	......	......	6.41	9.49	12.78	16.74	25.12	34.04
18	......	......	......	7.81	10.95	14.30	18.34	26.85	35.90
16	......	......	6.27	9.20	12.42	15.83	19.93	28.58	37.76
14	......	4.19	7.61	10.60	13.88	17.35	21.52	30.31	39.62
13	......	4.81	8.27	11.30	14.61	18.11	22.32	31.17	40.55
12	......	5.44	8.94	11.99	15.34	18.88	23.12	32.04	41.48
11	2.94	6.07	9.61	12.69	16.07	19.64	23.91	32.90	42.41
10	3.42	6.69	10.27	13.39	16.81	20.40	24.71	33.77	43.34
9	3.89	7.32	10.94	14.09	17.54	21.17	25.51	34.63	44.27
8	4.37	7.94	11.60	14.78	18.27	21.93	26.30	35.50	45.20
7	4.84	8.57	12.27	15.48	19.00	22.69	27.10	36.36	46.13
6	5.32	9.20	12.94	16.18	19.73	23.45	27.90	37.23	47.06
5	5.79	9.82	13.60	16.88	20.46	24.22	28.69	38.09	47.99

Length, feet	Size of pipe							
	8	9	10	11	12	13	14	15
	Thickness							
	.322	.342	.365	.375	.375	.375	.375	.375
40	24.04	33.53	45.38	55.49	64.44	75.63	84.58	93.53
36	28.02	37.76	49.90	60.12	69.07	80.26	89.21	98.17
33	31.00	40.93	53.28	63.60	72.55	83.74	92.69	101.64
30	33.99	44.10	56.66	67.08	76.03	87.22	96.17	105.12
27	36.97	47.27	60.05	70.55	79.51	90.69	99.65	108.60
24	39.96	50.44	63.43	74.03	82.98	94.17	103.12	112.08
22	41.95	52.55	65.69	76.35	85.30	96.49	105.44	114.40
20	43.94	54.66	67.94	78.67	87.62	98.81	107.76	116.71
18	45.93	56.78	70.20	80.99	89.94	101.13	110.08	119.03
16	47.92	58.89	72.46	83.30	92.26	103.45	112.40	121.35
14	49.90	61.01	74.71	85.62	94.57	105.76	114.72	123.67
13	50.90	62.06	75.84	86.78	95.73	106.92	115.88	124.83
12	51.89	63.12	76.97	87.94	96.89	108.08	117.03	125.99
11	52.89	64.18	78.10	89.10	98.05	109.24	118.19	127.15
10	53.88	65.23	79.22	90.26	99.21	110.40	119.35	128.31
9	54.88	66.29	80.35	91.42	100.37	111.56	120.51	129.47
8	55.87	67.35	81.48	92.57	101.53	112.72	121.67	130.62
7	56.87	68.40	82.61	93.73	102.69	113.88	122.83	131.78
6	57.86	69.46	83.74	94.89	103.85	115.04	123.99	132.94
5	58.86	70.52	84.86	96.05	105.00	116.20	125.15	134.10

NOTE. — Loads above or to the left of the zigzag line correspond to values of L/R greater than 120.

Standard Pipe Columns (Concluded)

(Loads in tons of 2000 pounds, based on Chicago Building Ordinances.)

$$S = 16\,000 - 70\,L/R.$$

S = allowable compressive stress for steel, pounds per square inch;
L = length of column in inches; R = least radius of gyration in inches;
Maximum allowable compressive stress = 14 000 pounds per square inch.

Length, feet	Size of pipe								
	2	2½	3	3½	4	4½	5	6	7
	Thickness								
	.154	.203	.216	.226	.237	.247	.258	.280	.301
40	......	......	......	......	......	......	......	......	......
36	......	......	......	......	......	......	......	......	15.00
33	......	......	......	......	......	......	......	10.20	18.37
30	......	......	......	......	......	......	......	13.33	21.73
27	......	......	......	......	......	......	8.43	16.46	25.10
24	......	......	......	......	......	7.41	11.32	19.60	28.47
22	......	......	......	......	5.96	9.25	13.24	21.68	30.71
20	......	......	......	4.60	7.73	11.09	15.16	23.77	32.96
18	......	......	......	6.28	9.50	12.94	17.09	25.86	35.20
16	......	......	4.96	7.97	11.26	14.78	19.01	27.95	37.45
14	......	3.06	6.57	9.65	13.03	16.62	20.93	30.04	39.69
13	......	3.81	7.37	10.49	13.91	17.54	21.90	31.08	40.81
12	......	4.57	8.18	11.33	14.79	18.46	22.86	32.12	41.94
11	2.29	5.32	8.98	12.18	15.68	19.38	23.82	33.17	43.06
10	2.86	6.08	9.78	13.02	16.56	20.30	24.78	34.21	44.18
9	3.44	6.83	10.59	13.86	17.44	21.22	25.74	35.26	45.30
8	4.01	7.59	11.39	14.70	18.33	22.14	26.71	36.30	46.43
7	4.58	8.34	12.20	15.54	19.21	23.06	27.67	37.34	47.55
6	5.16	9.10	13.00	16.38	20.09	23.98	28.63	38.39	48.48
5	5.73	9.86	13.81	17.23	20.98	24.90	29.59	39.07	48.48

Length, feet	Size of pipe							
	8	9	10	11	12	13	14	15
	Thickness							
	.322	.342	.365	.375	.375	.375	.375	.375
40	19.16	28.77	40.81	51.26	60.68	72.45	81.88	91.30
36	23.96	33.87	46.26	56.85	66.27	78.05	87.47	96.89
33	27.57	37.70	50.34	61.05	70.47	82.25	91.67	101.09
30	31.17	41.53	54.43	65.24	74.67	86.44	95.87	105.29
27	34.77	45.35	58.51	69.44	78.86	90.64	100.06	109.49
24	38.37	49.18	62.59	73.64	83.06	94.84	104.26	113.68
22	40.78	51.73	65.32	76.43	85.86	97.64	107.06	116.48
20	43.18	54.28	68.04	79.23	88.65	100.43	109.86	119.28
18	45.58	56.83	70.76	82.03	91.45	103.23	112.65	122.08
16	47.98	59.38	73.48	84.83	94.25	106.03	115.45	124.88
14	50.38	61.93	76.21	87.62	97.05	108.83	118.25	127.67
13	51.58	63.21	77.57	89.02	98.45	110.23	119.65	128.85
12	52.78	64.49	78.93	90.42	99.85	111.62	120.61	128.85
11	53.99	65.76	80.29	91.82	101.24	112.36	120.61	128.85
10	55.19	67.04	81.65	93.22	102.05	112.36	120.61	128.85
9	56.39	68.31	83.01	93.81	102.05	112.36	120.61	128.85
8	57.59	69.59	83.36	93.81	102.05	112.36	120.61	128.85
7	58.79	69.82	83.36	93.81	102.05	112.36	120.61	128.85
6	58.79	69.82	83.36	93.81	102.05	112.36	120.61	128.85
5	58.79	69.82	83.36	93.81	102.05	112.36	120.61	128.85

NOTE. — Loads above or to the left of the zigzag line correspond to values of L/R greater than 120.

Extra Strong Pipe Columns

(Loads in tons of 2000 pounds, based on New York Building Code.)

$$S = 15\,200 - 58\,L/R.$$

S = allowable compressive stress for steel, pounds per square inch;
L = length of column in inches;
R = least radius of gyration in inches.

Length, feet	Size of pipe								
	2	2½	3	3½	4	4½	5	6	7
	Thickness								
	.218	.276	.300	.318	.337	.355	.375	.432	.500
40	......	......	......	......	......	......	......	......	......
36	......	......	......	......	......	......	......	......	29.53
33	......	......	......	......	......	......	......	19.90	34.16
30	......	......	......	......	......	......	......	23.90	38.79
27	......	......	......	......	......	......	15.22	27.90	43.42
24	......	......	......	......	......	13.10	18.69	31.89	48.04
22	......	......	......	......	10.65	15.29	21.01	34.56	51.13
20	......	......	......	8.36	12.72	17.48	23.32	37.23	54.21
18	......	......	......	10.32	14.80	19.67	25.63	39.89	57.30
16	......	......	8.14	12.28	16.88	21.86	27.95	42.56	60.38
14	......	5.25	9.99	14.24	18.95	24.05	30.26	45.22	63.47
13	......	6.09	10.91	15.22	19.99	25.14	31.42	46.55	65.01
12	......	6.94	11.84	16.20	21.03	26.24	32.57	47.89	66.55
11	3.85	7.79	12.76	17.18	22.07	27.33	33.73	49.22	68.09
10	4.52	8.64	13.68	18.16	23.11	28.43	34.89	50.55	69.64
9	5.19	9.49	14.61	19.14	24.15	29.52	36.04	51.88	71.18
8	5.86	10.34	15.53	20.12	25.19	30.61	37.20	53.22	72.72
7	6.53	11.19	16.46	21.10	26.23	31.71	38.35	54.55	74.26
6	7.20	12.03	17.38	22.08	27.26	32.80	39.51	55.88	75.80
5	7.87	12.88	18.30	23.06	28.30	33.90	40.67	57.21	77.35

Length, feet	Size of pipe							
	8	9	10	11	12	13	14	15
	Thickness							
	.500	.500	.500	.500	.500	.500	.500	.500
40	35.27	47.18	60.59	72.52	84.45	99.36	111.29	123.23
36	41.44	53.36	66.77	78.70	90.63	105.54	117.47	129.41
33	46.07	57.99	71.40	83.33	95.26	110.18	122.11	134.04
30	50.70	62.62	76.04	87.97	99.90	114.81	126.75	138.68
27	55.33	67.25	80.67	92.60	104.53	119.45	131.38	143.32
24	59.96	71.88	85.30	97.23	109.17	124.08	136.02	147.95
22	63.05	74.97	88.39	100.32	112.25	127.17	139.11	151.04
20	66.13	78.06	91.48	103.41	115.34	130.26	142.20	154.13
18	69.22	81.15	94.57	106.50	118.43	133.35	145.29	157.22
16	72.31	84.23	97.66	109.59	121.52	136.44	148.38	160.31
14	75.39	87.32	100.74	112.68	124.61	139.53	151.47	163.41
13	76.94	88.87	102.29	114.22	126.16	141.08	153.01	164.95
12	78.48	90.41	103.83	115.77	127.70	142.62	154.56	166.50
11	80.02	91.95	105.38	117.31	129.25	144.17	156.10	168.04
10	81.56	93.50	106.92	118.86	130.79	145.71	157.65	169.59
9	83.11	95.04	108.47	120.40	132.34	147.26	159.19	171.13
8	84.65	96.58	110.01	121.95	133.88	148.80	160.74	172.68
7	86.19	98.13	111.56	123.49	135.43	150.35	162.29	174.22
6	87.74	99.67	113.10	125.04	136.97	151.89	163.83	175.77
5	89.28	101.22	114.64	126.58	138.52	153.44	165.38	177.31

NOTE. — Loads above or to the left of the zigzag line correspond to values of L/R greater than 120.

Extra Strong Pipe Columns (Concluded)

(Loads in tons of 2000 pounds, based on Chicago Building Ordinances.)

$$S = 16\,000 - 70\,L/R.$$

S = allowable compressive stress for steel, pounds per square inch;
L = length of column in inches; R = least radius of gyration in inches;
Maximum allowable compressive stress = 14 000 pounds per square inch.

Length, feet	Size of pipe								
	2	2½	3	3½	4	4½	5	6	7
	Thickness								
	.218	.276	.300	.318	.337	.355	.375	.432	.500
40	......	......	......	......	......	......	......	......	......
36	......	......	......	......	......	......	......	......	22.52
33	......	......	......	......	......	......	......	14.16	28.11
30	......	......	......	......	......	......	......	18.99	33.69
27	......	......	......	......	......	......	11.21	23.81	39.28
24	......	......	......	......	......	9.74	15.39	28.64	44.86
22	......	......	......	......	7.68	12.38	18.19	31.86	48.58
20	......	......	......	5.78	10.19	15.02	20.98	35.07	52.31
18	......	......	......	8.14	12.69	17.66	23.77	38.29	56.03
16	......	......	6.29	10.51	15.20	20.31	26.56	41.51	59.75
14	......	3.69	8.52	12.87	17.71	22.95	29.35	44.72	63.48
13	......	4.71	9.64	14.06	18.96	24.27	30.75	46.33	65.34
12	......	5.74	10.75	15.24	20.22	25.59	32.15	47.94	67.20
11	2.91	6.76	11.87	16.42	21.47	26.91	33.54	49.55	69.06
10	3.72	7.79	12.98	17.60	22.72	28.23	34.94	51.16	70.92
9	4.53	8.81	14.09	18.79	23.98	29.55	36.33	52.76	72.78
8	5.34	9.83	15.21	19.97	25.23	30.88	37.73	54.37	74.64
7	6.15	10.86	16.32	21.15	26.48	32.20	39.12	55.98	76.51
6	6.96	11.88	17.44	22.33	27.74	33.52	40.52	57.59	78.34
5	7.77	12.91	18.55	23.52	28.99	34.84	41.92	58.83	78.34

Length, feet	Size of pipe							
	8	9	10	11	12	13	14	15
	Thickness							
	.500	.500	.500	.500	.500	.500	.500	.500
40	27.60	40.14	54.25	66.80	79.36	95.06	107.62	120.18
36	35.05	47.59	61.71	74.26	86.82	102.52	115.08	127.64
33	40.64	53.18	67.30	79.85	92.41	108.11	120.67	133.23
30	46.23	58.77	72.89	85.45	98.00	113.70	126.27	138.83
27	51.81	64.36	78.48	91.04	103.60	119.30	131.86	144.42
24	57.40	69.95	84.07	96.63	109.19	124.89	137.45	150.02
22	61.13	73.68	87.80	100.36	112.92	128.62	141.18	153.75
20	64.85	77.40	91.53	104.09	116.65	132.35	144.91	157.48
18	68.58	81.13	95.26	107.82	120.38	136.08	148.64	161.21
16	72.30	84.86	98.98	111.54	124.11	139.81	152.37	164.94
14	76.03	88.58	102.71	115.27	127.84	143.54	156.10	168.67
13	77.89	90.45	104.58	117.14	129.70	145.40	157.97	170.43
12	79.75	92.31	106.44	119.00	131.56	147.27	159.44	170.43
11	81.61	94.17	108.30	120.87	133.43	148.44	159.44	170.43
10	83.48	96.04	110.17	122.73	134.70	148.44	159.44	170.43
9	85.34	97.90	112.03	123.70	134.70	148.44	159.44	170.43
8	87.20	99.76	112.70	123.70	134.70	148.44	159.44	170.43
7	89.06	100.33	112.70	123.70	134.70	148.44	159.44	170.43
6	89.34	100.33	112.70	123.70	134.70	148.44	159.44	170.43
5	89.34	100.33	112.70	123.70	134.70	148.44	159.44	170.43

NOTE. — Loads above or to the left of the zigzag line correspond to values of L/R greater than 120.

Double Extra Strong Pipe Columns

(Loads in tons of 2000 pounds, based on New York Building Code.)

$$S = 15\,200 - 58\,L/R.$$

S = allowable compressive stress for steel, pounds per square inch;
L = length of column in inches; R = least radius of gyration in inches.

Length, feet	Size of pipe									
	2	2½	3	3½	4	4½	5	6	7	8
	Thickness									
	.436	.552	.600	.636	.674	.710	.750	.864	.875	.875
40	.....	.....	.....	.....	.....	.....	.....	.....	.....	54.36
36	.....	.....	.....	.....	.....	.....	.....	.....	44.42	65.12
33	.....	.....	.....	.....	.....	.....	.....	31.65	52.47	73.18
30	.....	.....	.....	.....	.....	.....	.....	39.58	60.52	81.25
27	.....	.....	.....	.....	.....	.....	24.32	47.51	68.57	89.32
24	.....	.....	.....	.....	.....	20.74	31.19	55.43	76.62	97.38
22	.....	.....	.....	.....	16.41	25.07	35.77	60.72	81.99	102.76
20	.....	.....	.....	12.43	20.52	29.40	40.36	66.00	87.35	108.14
18	.....	.....	.....	16.30	24.62	33.74	44.94	71.28	92.72	113.51
16	.....	.....	12.47	20.16	28.73	38.07	49.52	76.57	98.09	118.89
14	.....	7.37	16.11	24.03	32.83	42.40	54.11	81.85	103.45	124.27
13	.....	9.03	17.93	25.96	34.89	44.57	56.40	84.50	106.14	126.96
12	.....	10.69	19.74	27.89	36.94	46.73	58.69	87.14	108.82	129.65
11	5.72	12.35	21.56	29.83	38.99	48.90	60.98	89.78	111.50	132.33
10	7.03	14.01	23.38	31.76	41.04	51.06	63.27	92.42	114.19	135.02
9	8.35	15.67	25.19	33.69	43.10	53.23	65.56	95.06	116.87	137.71
8	9.66	17.33	27.01	35.62	45.15	55.40	67.85	97.71	119.55	140.40
7	10.98	18.99	28.83	37.56	47.20	57.56	70.15	100.35	122.24	143.09
6	12.29	20.65	30.64	39.49	49.25	59.73	72.44	102.99	124.92	145.78
5	13.61	22.31	32.46	41.42	51.31	61.89	74.73	105.63	127.60	148.47

Double Extra Strong Pipe Columns (Concluded)

(Loads in tons of 2000 pounds, based on Chicago Building Ordinances.)

$S = 16\,000 - 70\,L/R.$ (S, L, R, same as above.)

Maximum allowable compressive stress = 14 000 pounds per square inch.

40	.....	.....	.....	.....	.....	.....	.....	.....	.....	40.64
36	.....	.....	.....	.....	.....	.....	.....	.....	31.86	53.61
33	.....	.....	.....	.....	.....	.....	.....	19.87	41.57	63.35
30	.....	.....	.....	.....	.....	.....	.....	29.43	51.29	73.08
27	.....	.....	.....	.....	.....	.....	16.05	39.00	61.00	82.82
24	.....	.....	.....	.....	.....	13.81	24.35	48.57	70.72	92.55
22	.....	.....	.....	.....	10.31	19.04	29.88	54.94	77.19	99.04
20	.....	.....	.....	7.13	15.27	24.27	35.41	61.32	83.67	105.53
18	.....	.....	.....	11.79	20.22	29.50	40.94	67.70	90.15	112.02
16	.....	.....	8.65	16.46	25.17	34.73	46.47	74.08	96.63	118.51
14	.....	4.17	13.03	21.12	30.13	39.95	52.00	80.46	103.10	125.00
13	.....	6.17	15.22	23.45	32.61	42.57	54.77	83.64	106.34	128.25
12	.....	8.18	17.42	25.78	35.08	45.18	57.54	86.83	109.58	131.49
11	3.78	10.18	19.61	28.12	37.56	47.80	60.30	90.02	112.82	134.74
10	5.37	12.18	21.80	30.45	40.04	50.41	63.07	93.21	116.06	137.98
9	6.96	14.19	24.00	32.78	42.52	53.02	65.83	96.40	119.29	141.23
8	8.55	16.19	26.19	35.11	44.99	55.64	68.60	99.59	122.53	144.47
7	10.13	18.20	28.38	37.45	47.47	58.25	71.36	102.78	125.77	147.72
6	11.72	20.20	30.57	39.78	49.95	60.87	74.13	105.97	129.01	149.13
5	13.31	22.21	32.77	42.11	52.42	63.48	76.89	109.15	129.89	149.13

NOTE. — Loads above or to the left of the zigzag line correspond to values of L/R greater than 120.

MECHANICAL PROPERTIES OF SOLID AND TUBULAR BEAMS

All those parts of a structure, such as a simple lever, an automobile axle, or a trolley pole, which have to resist bending actions are known as beams.

The bending actions upon a beam give rise to both stresses and deformations, whose precise nature will of course depend upon the manner of support and the nature of the loading. These will be treated, in what follows, for straight solid and tubular beams having a uniform cross section throughout their lengths.

Tensile and Compressive Stresses in Beams. The principal stresses in a loaded beam are tension and compression. These are illustrated in Fig. 119 for the case of a beam supported at the ends and loaded at the middle. In this case the lower longitudinal fibers are subjected to tensile stress, while the upper fibers are subjected to compressive stress. The former will, therefore, lengthen and the latter shorten to an extent that will depend upon the amount of the loading. Within the elastic limit of the material the lengthening or shortening of any fiber is directly proportional to its distance from the neutral surface, JJ.

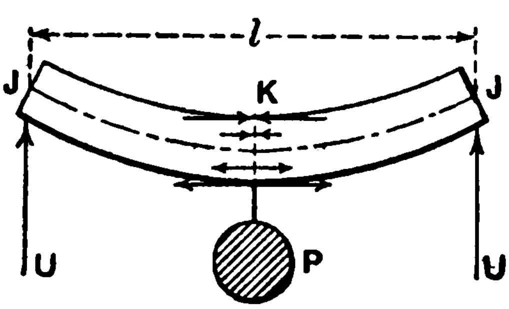


Fig. 119

For steel, and other similar elastic materials not stressed beyond the elastic limit, the *neutral surface*, JJ, will always pass through the centers of gravity of the different cross sections. This neutral surface will of course always divide the beam longitudinally into two parts, one of which is subjected to tensile stress and the other to compressive stress. The stresses on the individual fibers of a loaded beam are proportional to their distances from the neutral surface, when all stresses are less than the elastic limit of the material. There is of course no stress upon the fibers lying in the neutral surface, this being the place where the stress passes from tension on one side to compression on the other.

While selecting a value for the working fiber stress, when applying the formulæ given in the table, pages 258 to 263, of the Properties of Solid and Tubular Beams, it should be remembered (1) that the fiber of a beam that is subjected to the greatest stress is the one that lies at the greatest distance from the neutral surface, and (2) that this most remote fiber in practice should never be stressed beyond a certain fraction of the elastic limit of the material, the value of the fraction depending upon the nature and frequency of the loading. See pages 268 to 270.

Shearing Stress in Beams. Every beam when loaded is subjected to a transverse stress that tends to shear the beam across, as illustrated at section YY of Fig. 120. The *vertical shear*, s, for any section of a beam is the algebraic sum of all the external vertical forces on either

side of that section, upward forces, or reactions, being considered as positive, and downward forces or loads as negative to the left of the section. To the right of the section the algebraic signs are reversed. When s is positive, as at section YY, Fig. 120, the part of the beam to the left of the section tends to slide upward with respect to the part to the right, and when s is negative the left-hand part tends to slide downward with respect to the right-hand part.

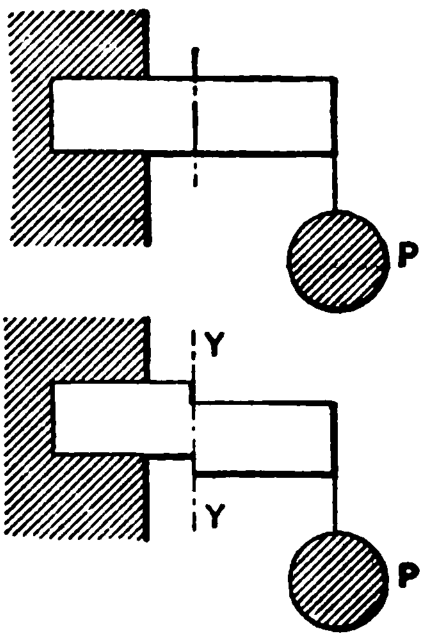


Fig. 120

In most cases the shearing action may be ignored for steel beams, especially for those having comparatively bulky cross sections, such as tubes with sufficiently thick walls relative to their diameters. When, however, the beam is very short, or the loading is quite close to a support, or the web is comparatively thin, then the shearing stress may become of equal or even greater importance than the tension or compression in the beam, in which case it should be taken into consideration.

In the table, pages 258 to 263, of the Properties of Solid and Tubular Beams, the maximum numerical values of the shearing stress will be found tabulated for the different kinds of beam support and loading. The locations of these maximum shears are also given.

Elastic Curve. Since the materials of which beams are constructed are more or less elastic, a beam under load will assume a curved form. The nature of this curve will of course depend upon the manner of support and loading.

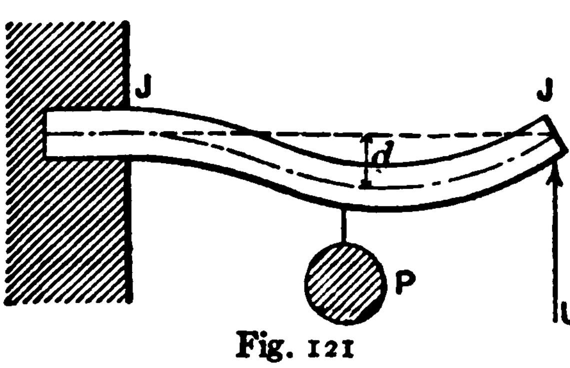


Fig. 121

Fig. 121 shows in a general way the curved form assumed by a beam that is fixed at one end, supported at the other, and loaded at the middle point of its length. The curved line JJ assumed by the neutral axis of the beam, the material not being stressed beyond the elastic limit, is known as the elastic curve. This curve is of the greatest importance in the theoretical discussion of beams.

Elastic Deflection of Beams. The greatest departure of the elastic curve of a loaded beam from the position of the neutral surface when the beam is in an unloaded condition is known as the elastic deflection of the beam. This is shown as d in Fig. 121, and is also represented by the same letter in the different formulæ of the table, pages 258 to 263, of the Properties of Solid and Tubular Beams. It is to be understood, of course, that these formulæ apply only to beams of uniform cross section and when the most strained fiber of the beam is not stressed beyond the elastic limit of the material.

Reactions of Supports. Two kinds of external forces act upon a beam. These are the loads which tend to move the beam bodily downward and the reactions of the supports which oppose this tendency.

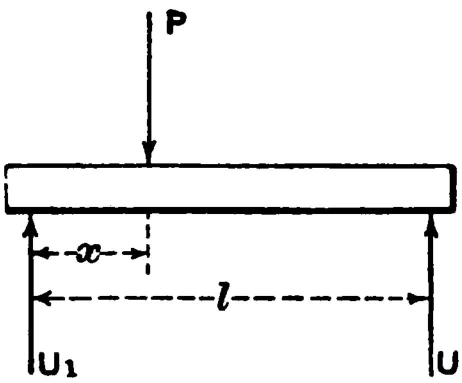


Fig. 122

Thus, in Fig. 122, the load P acting downward, because of the rigidity of the beam, will be carried to the supports, and will rest upon them jointly. The portion of the load, in this case, carried by the left support, will be $\frac{l-x}{l}P$. The reaction offered by that support, then, will be $U_1 = \frac{l-x}{l}P$, and similarly that carried by the right-hand support will be $U_2 = \frac{x}{l}P$.

It is a fundamental principle of mechanics that the sum of the reactions must equal the sum of the loading, or, in the case of the simple beam shown in Fig. 122, $U_1 + U_2 = P$.

In the table of the Properties of Solid and Tubular Beams, pages 258 to 263, the reactions, designated by U, are given for the different kinds of support and loading, and are expressed in the same unit as the loading.

It should be noted that these formulæ assume that the reactions act in directions that are parallel to the action of the loading, that is to say, in Fig. 122, the forces U_1, U_2, and P all act in parallel directions.

When a simple beam is subjected at the same time to both uniform and concentrated loads, the reaction may be obtained by taking the sum of the respective reactions due to the uniform load and to each concentrated load.

Bending Moment. The chief action of the external forces upon a beam is most easily expressed as a bending moment, which is the tendency of the external forces to produce rotation of the beam around any of its sections. Thus, in Fig. 123, the force P, acting downward at the free end, will tend to cause a bodily rotation of the beam in a downward direction about the section KK, at the fixed end.

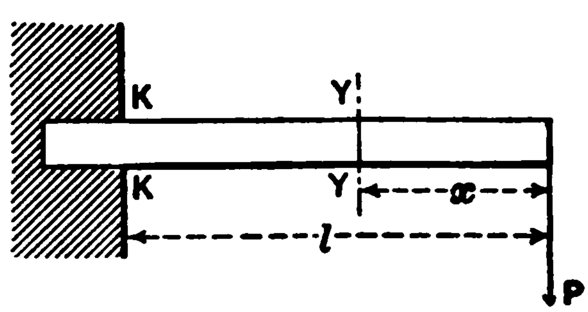


Fig. 123

This tendency to rotate is measured by the force, P, multiplied by the *lever arm*, l, the result, Pl, being the bending moment at the section KK. Similarly, the bending moment at any other section YY will be Px. A bending moment is commonly expressed in inch pounds, the lever arm being stated in inches and the force in pounds.

Considering the portion of a beam that lies to the left of any section, bending moments that tend to cause rotation in a clockwise direction are taken as positive, while those that tend to cause rotation in the opposite direction are taken as negative. For that portion that lies to the right of any section, bending moments that tend to cause rotation

in a clockwise direction are negative, while those that tend to cause rotation in the opposite direction are positive.

The bending moment at any section of a beam is equal to the algebraic sum of the moments of all the external forces on either side of that section.

In case the force P does not act in a direction at right angles to the beam, then the lever arm is to be taken as the perpendicular or shortest distance from the section considered to the line of action of the force. Thus, in Fig. 124, the lever arm is $x = l \sin a$ for the fixed end of the inclined beam, and the corresponding bending moment will be $Pl \sin a$, a being the angle that the line of action of the loading, or other force, makes with the axis of the beam.

Fig. 124

The bending moments of the table of the Properties of Solid and Tubular Beams, pages 258 to 263, are expressed in inch pounds, and assume that the direction of loading is at right angles to the direction of the beam when in its unloaded condition.

Resisting Moment. The strength of a beam to resist bending action is known as its resisting moment. Thus, in Fig. 125, which represents a beam fixed at one end and loaded at the other, the external force P will evidently give rise to stresses that are held in equilibrium by the internal forces shown. These internal resisting forces, shown in this case for section KK, are due to the tensile strength of the material of the beam lying above the neutral surface JJ, and to the compressive strength of the material lying below JJ. The beam in this case tends to rotate downward about the center of gravity of the section KK, and this tendency is precisely counteracted by the internal forces shown. It is evident that the bending moment Pl, Fig. 125, must equal the sum of the individual moments of each of the internal resisting forces shown, all lever arms being measured from the center of gravity of section KK. In works on mechanics it is shown that this sum, or the total resisting moment, is, for steel not stressed beyond the elastic limit,

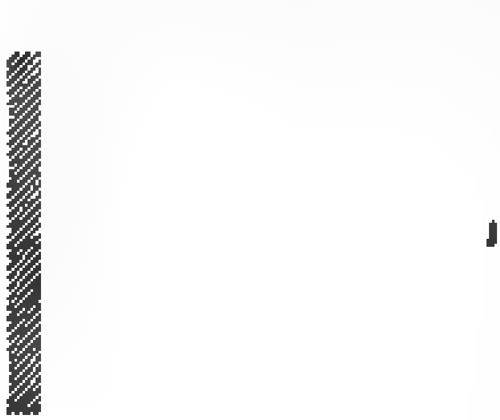


Fig. 125

$$M_r = fZ = f\frac{I}{y}, \qquad (1)$$

where M_r = resisting moment in inch pounds;

f = stress on farthest fiber from neutral surface JJ, in pounds per square inch;

I = moment of inertia of cross section;

y = distance of farthest fiber from neutral surface JJ;

Z = section modulus = I/y.

Moment of Inertia, I, and Section Modulus, Z. These are the properties of the cross section that determine respectively the elasticity and strength of beams. By referring to the table of the Properties of Solid and Tubular Beams, pages 258 to 263, it will be observed that every deflection formula contains as a factor the reciprocal of the moment of inertia of cross section, I, and that every formula for the strength of beams contains as a factor the section modulus, Z. Other things being equal, then, the stiffness of beams will be proportional to their moments of inertia of cross section, while the strengths will be proportional to their section moduli.

These two properties of the cross sections of beams are, therefore, of the greatest importance in the practical application of mechanics to all parts of structures that are subjected to bending actions. The relation of these two properties is such that the value of the section modulus can be obtained by dividing the corresponding moment of inertia by the distance of the farthest fiber from the neutral axis, or

$$Z = \frac{I}{y}. \qquad (2)$$

These properties of the cross section of pipe can be obtained from the table of properties, pages 58 to 65. For Seamless Tubing see tables, pages 204 and 205. For other sizes use table, pages 424 to 459. For the properties of cross sections other than circular see tables, pages 264 to 267.

Strength of Beams. In order that a beam for any kind of support and loading may have sufficient strength, the following conditions must be satisfied:

1. The resisting moment due to the internal longitudinal stresses at any section must equal the bending moment at that section due to the external forces, or

$$fZ = f\frac{I}{y} = M. \qquad (3)$$

2. The resisting shear due to the internal transverse stresses at any section must equal the transverse shear at that section due to the external forces, or

$$f_s A = S, \qquad (4)$$

where M = bending moment in inch pounds;
I = moment of inertia of cross section;
Z = section modulus;
y = distance from farthest fiber to neutral axis in inches;
A = area of cross section in square inches;
f = safe working fiber stress in pounds per square inch;
f_s = safe working shearing stress in pounds per square inch;
S = shearing force in pounds.

Comparative Strength of Beams. The strength of a beam is measured by the load that it can carry when the most strained fiber is stressed to the safe working strength of the material. An examination of the beam formulæ, pages 258 to 263, will show, for well-proportioned beams, where the tendency to shear, crimp, or buckle is kept subordinate, that the strength of beams for any kind of support and loading will vary (1) directly as the safe working fiber stress of the material, f_s, (2) directly as the section modulus, Z, and (3) inversely as the length of beam, l.

It is apparent, then, that for similar beams of given material, length, and weight, the one which has the greatest section modulus, Z, will be the strongest. For example, the strength of a tubular beam which is 4 inches diameter by ½ inch wall, as compared with that of a similar solid round beam of the same length, weight, and manner of support and loading, will be as follows: The weight of the tubular beam is 18.69 pounds per foot. From the table, page 429, the diameter of a solid round beam of the same weight is found to be 2.65 inches. The respective section moduli are, then, 4.30 and 1.83. This tubular beam will, then, be theoretically 2.4 times as strong as a similar solid round beam of the same length and weight.

It should be remembered that for extreme cases, where beams tend to fail by shearing, crimping, or lateral buckling, the above simple relations do not strictly apply. For well-proportioned beams, however, these laws apply with sufficient accuracy for practical purposes, irrespective of the manner of support and loading.

Comparative Stiffness of Beams. The stiffness of a beam is indicated by the load that it can carry with a given deflection. An examination of the beam formulæ, pages 258 to 263, will show that the stiffness of a beam, when stressed within the elastic limit of the material, for any kind of support and loading, varies (1) directly as the modulus of elasticity of the material, E, (2) directly as the moment of inertia of cross section, I, and (3) inversely as the cube of the length of beam, l^3.

Other things being equal, then, the stiffness of beams is directly proportional to their moments of inertia of cross section, I. For example, the above tubular beam, whose strength was shown to be 2.4 times that of a similar solid round beam of the same length, weight, and manner of support and loading, will be found to be 3.5 times as stiff, since their respective moments of inertia of cross section are as 8.59 to 2.42.

Sections Giving Minimum Weight of Beams for a Given Strength or Stiffness. For material, such as steel, which has practically the same physical properties in tension as in compression, the most economical forms of beam cross section are as follows:

1. For *vertical loading only*, that is to say, for loading in a single direction, a beam of given length will have a minimum weight for a given strength or stiffness when it has the "I" section shown in Fig. 126. This form of cross section permits of the most advantageous disposition of the material to resist stress for loading in a single direction, because for this condition both the moments of inertia of cross section, I, and the section modulus, Z, can be made a maximum.

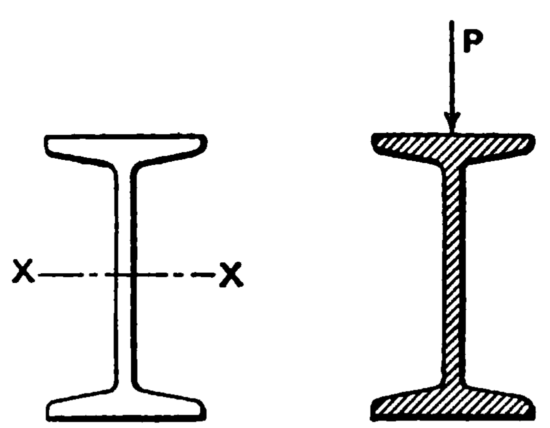


Fig. 126

When designing beams of this character it should be remembered, however, that sufficient material must be put in the web to resist the greatest shear, and that the width of the flange in compression must be

sufficient to prevent lateral buckling. Sufficient material must also be put into the web to prevent crushing or buckling of the web underneath the loading and at the supports.

2. For *vertical and horizontal loading*, that is to say, for loading in two directions at right angles to each other, a beam of given length will have a minimum weight for a given strength or stiffness when it has the hollow rectangular section shown in Fig. 127. This form of cross section permits of the most advantageous disposition of the material to resist stresses, for the conditions assumed, since, for this form of beam, the moments of inertia, I, and the section moduli, Z, for a given sectional area, can be made a maximum for both the vertical and horizontal bending actions. When these two actions are equal the cross section should of course be a hollow square.

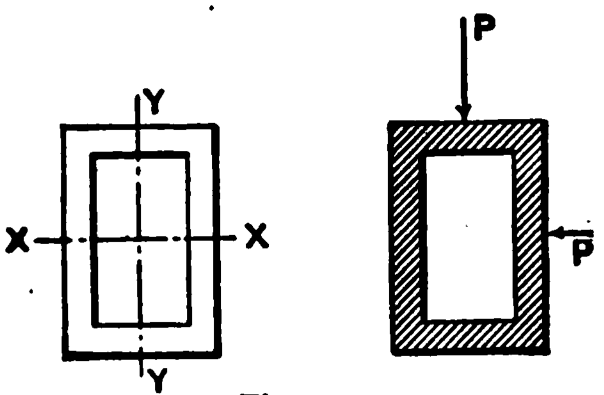


Fig. 127

3. For *equal loading in any direction*, a beam of given length will have a minimum weight for a given strength or stiffness when it has the tubular section shown in Fig. 128. The ordinary tubular form of beam permits of the most advantageous disposition of the material to resist stresses for the conditions assumed, since for the circular section the moment of inertia of cross section, I, and the section modulus, Z, can be made a maximum for loading in all directions around the beam.

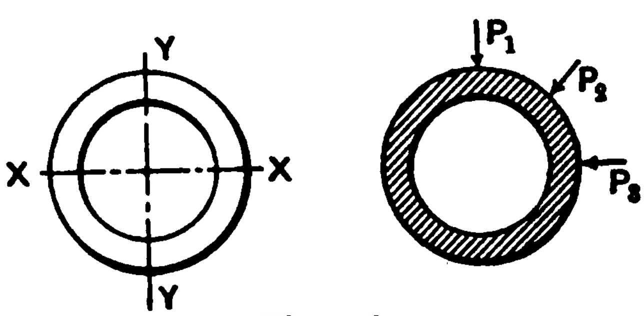


Fig. 128

It is evident that the cylindrical tubular beam will approximate closely to a hollow square beam with respect to strength and stiffness for equal loading in directions at right angles to each other; also, that the hollow oval section will give results approximating closely to those of the hollow rectangular section, Fig. 127.

TABLE OF THE MECHANICAL PROPERTIES OF SOLID AND TUBULAR BEAMS OF UNIFORM CROSS SECTION

This table of the mechanical properties of beams is based upon the assumptions: (1) that the beam is straight when in its unloaded condition; (2) that it has a uniform cross section from end to end; and (3) that the directions of the loading and reactions lie in the same plane and are at right angles to the axis of the beam when in its unloaded condition.

All the formulæ contained in this table of the properties of beams have been calculated anew, because it was desired to eliminate any errors and misprints in the data on beams as found in the different standard works on mechanics.

Notation. In this table of the mechanical properties of beams the following notation is used:

A = area of cross section of beam in square inches. For a hollow, or tubular beam, the area of the actual wall cross section must be used.

D = diameter of a solid round beam, in inches, or the outside diameter of a tubular beam.

d = greatest deflection of a beam, in inches, or the greatest deviation from straightness when the beam is subjected to a given loading.

E = modulus of elasticity of the material in pounds. The value of E is approximately 29 000 000 for steel tubing, as obtained by experiments on long tubular beams.

f = fiber stress in pounds per square inch on the most strained fiber of the beam.

f_s = shearing stress in pounds per square inch of cross section of the beam.

I = moment of inertia of cross section of the beam.
Values of I for pipe can be obtained from the table of properties, pages 58 to 65. For Seamless Tubing see table, pages 204 and 205. For other sizes use table, pages 424 to 459. For sections that are not round see table, pages 264 to 267.

J = polar moment of inertia. For circular sections: $J = 2\,I$.

l = length of beam in inches.

M = bending moment in inch pounds due to the loading on the beam. The greatest value of M and its location, for each style of beam support and loading, is tabulated to the left and shown on the moment diagram to the right, immediately underneath the figure of the beam.

M_r = resisting moment of the beam cross section in inch pounds $= fZ$.

P = pressure in pounds due to a load or force acting at right angles to the axis of a beam.

R = radius of gyration of cross section in inches $= \sqrt{I \div A}$.
Values of R for pipe can be obtained from the table of properties, pages 58 to 65. For Seamless Tubing see table, pages 206 and 207. For other sizes see table, pages 424 to 459. For sections that are not round see table, pages 264 to 267.

S, S_1, S_2 = vertical shearing forces in pounds acting on the beam, due to the loading.

U, U_1, U_2 = reactions of the supports of a beam in pounds.

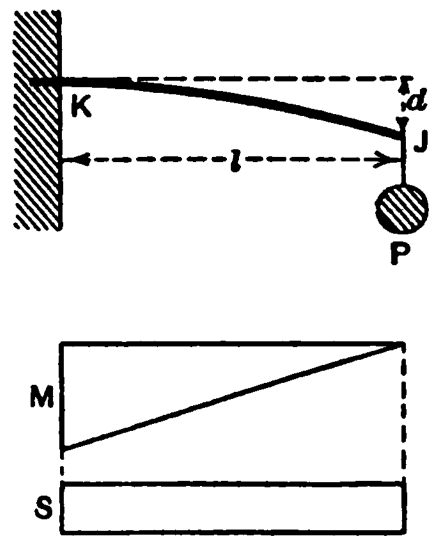
W = weight of a beam in pounds per lineal inch, also weight of a uniformly distributed load in pounds per lineal inch.

y = distance from neutral axis of beam to the most distant fiber in inches. Values of y for tubular beams are given in the table, pages 424 to 459.

Z = section modulus, or $I \div y$.
Values of Z for pipe are given in the table of properties, pages 58 to 65. For Seamless Tubing see table, pages 204 and 205. For other sizes calculate from the corresponding values of I and y, in the table, pages 424 to 459. For sections that are not round see table, pages 264 to 267.

Properties of Solid and Tubular Beams

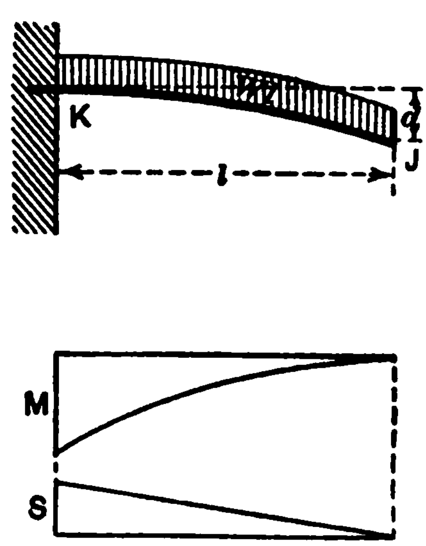
1. Greatest bending moment, at K . . . . Pl
2. Greatest fiber stress, at K . . . . $\dfrac{Ply}{I}$ or $\dfrac{Pl}{Z}$
3. Greatest safe load . . . . $\dfrac{fI}{ly}$ or $\dfrac{fZ}{l}$
4. Section modulus (Z) . . . . $\dfrac{Pl}{f}$
5. Greatest deflection, at J . . . . . . $\dfrac{Pl^3}{3\,EI}$ or $\dfrac{fl^2}{3\,Ey}$
6. Moment of inertia (I) . . . . $\dfrac{Pl^3}{3\,Ed}$
7. Load in terms of deflection . . . . $\dfrac{3\,EId}{l^3}$
8. Fiber stress in terms of deflection . . . . $\dfrac{3\,Eyd}{l^2}$
9. Greatest shear, from J to K . . . . P



I. Beam fixed at one end and loaded at the other.

---

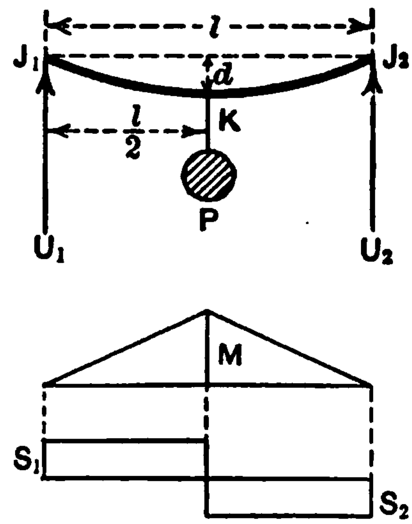
1. Greatest bending moment, at K . . . . $\dfrac{Wl^2}{2}$
2. Greatest fiber stress, at K . . . . . $\dfrac{Wl^2y}{2\,I}$ or $\dfrac{Wl^2}{2\,Z}$
3. Greatest safe load . . . . $\dfrac{2\,fI}{ly}$ or $\dfrac{2\,fZ}{l}$
4. Section modulus (Z) . . . . $\dfrac{Wl^2}{2\,f}$
5. Greatest deflection, at J . . . . . . $\dfrac{Wl^4}{8\,EI}$ or $\dfrac{fl^2}{4\,Ey}$
6. Moment of inertia (I) . . . . $\dfrac{Wl^4}{8\,Ed}$
7. Load in terms of deflection . . . . $\dfrac{8\,EId}{l^4}$
8. Fiber stress in terms of deflection . . . . $\dfrac{4\,Eyd}{l^2}$
9. Greatest shear, at K . . . . Wl



II. Beam fixed at one end and uniformly loaded.

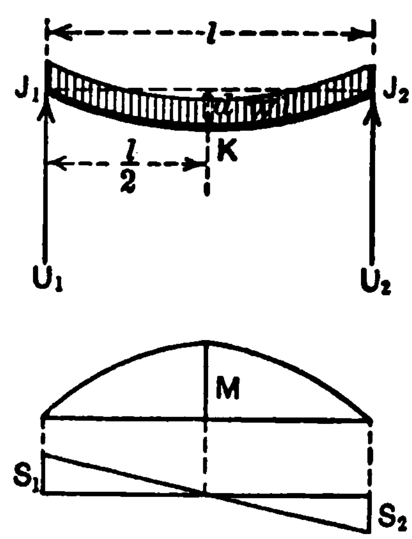
Properties of Solid and Tubular Beams (Continued)

1. Greatest bending moment, at K....... $\frac{Pl}{4}$
2. Greatest fiber stress, at K.... $\frac{Ply}{4I}$ or $\frac{Pl}{4Z}$
3. Greatest safe load........... $\frac{4fI}{ly}$ or $\frac{4fZ}{l}$
4. Section modulus (Z)................ $\frac{Pl}{4f}$
5. Greatest deflection, at K.. $\frac{Pl^3}{48EI}$ or $\frac{fl^2}{12Ey}$
6. Moment of inertia (I)............. $\frac{Pl^3}{48Ed}$
7. Load in terms of deflection....... $\frac{48EId}{l^3}$
8. Fiber stress in terms of deflection.. $\frac{12Eyd}{l^2}$
9. Greatest shear, J_1 to J_2.............. $\frac{P}{2}$
10. Reactions................. $U_1 = U_2 = \frac{P}{2}$



III. Beam supported at both ends and loaded at the middle.

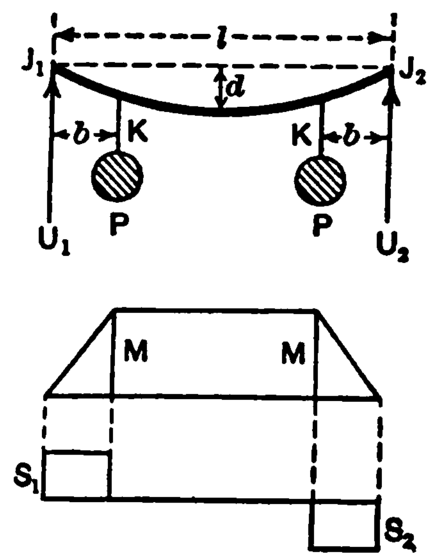
1. Greatest bending moment, at K...... $\frac{Wl^2}{8}$
2. Greatest fiber stress, at K.... $\frac{Wl^2y}{8I}$ or $\frac{Wl^2}{8Z}$
3. Greatest safe load........... $\frac{8fI}{ly}$ or $\frac{8fZ}{l}$
4. Section modulus (Z)............... $\frac{Wl^2}{8f}$
5. Greatest deflection, at K, $\frac{5Wl^4}{384EI}$ or $\frac{5fl^2}{48Ey}$
6. Moment of inertia (I)........... $\frac{5Wl^4}{384Ed}$
7. Load in terms of deflection...... $\frac{384EId}{5l^3}$
8. Fiber stress in terms of deflection.. $\frac{48Eyd}{5l^2}$
9. Greatest shear, at ends of beam...... $\frac{Wl}{2}$
10. Reactions............... $U_1 = U_2 = \frac{Wl}{2}$



IV. Beam supported at both ends and uniformly loaded.

Properties of Solid and Tubular Beams (Continued)

1. Greatest bending moment, K to K...... Pb
2. Greatest fiber stress, K to K.... $\dfrac{Pby}{I}$ or $\dfrac{Pb}{Z}$
3. Greatest safe load............... $\dfrac{fI}{by}$ or $\dfrac{fZ}{b}$
4. Section modulus (Z)................. $\dfrac{Pb}{f}$
5. Greatest deflection $\dfrac{Pb}{6\,EI}\left(\frac{3}{4}\,l^2 - b^2\right)$ or $\dfrac{f}{6\,Ey}\left(\frac{3}{4}\,l^2 - b^2\right)$
6. Moment of inertia (I)...... $\dfrac{Pb}{6\,Ed}\left(\frac{3}{4}\,l^2 - b^2\right)$
7. Load in terms of deflection..... $\dfrac{6\,EId}{b\left(\frac{3}{4}\,l^2 - b^2\right)}$
8. Fiber stress in terms of deflection.. $\dfrac{6\,Eyd}{\frac{3}{4}\,l^2 - b^2}$
9. Greatest shear, from each end to load.... P
10. Reactions.................. $U_1 = U_2 = P$

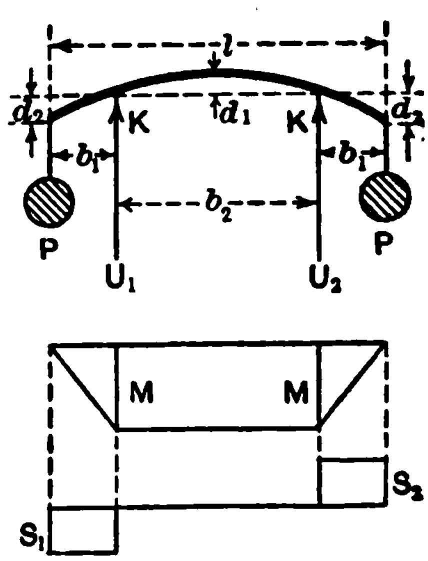


V. Beam supported at both ends, with two equal symmetrical loads.

---

1. Greatest bending moment, K to K..... Pb_1
2. Greatest fiber stress, K to K... $\dfrac{Pb_1y}{I}$ or $\dfrac{Pb_1}{Z}$
3. Greatest safe load............. $\dfrac{fI}{b_1y}$ or $\dfrac{fZ}{b_1}$
4. Section modulus (Z)................ $\dfrac{Pb_1}{f}$
5. Greatest deflection...... $d_1 = \dfrac{Pb_1b_2^2}{8\,EI}$ or $\dfrac{fb_2^2}{8\,Ey}$

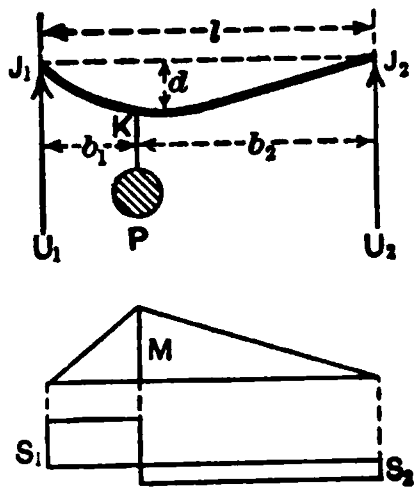
   $d_2 = \dfrac{Pb_1}{6\,EI}(3\,lb_1 - 4\,b_1^2)$ or $\dfrac{f}{6\,Ey}(3\,lb_1 - 4\,b_1^2)$
6. Moment of inertia (I) $\dfrac{Pb_1b_2^2}{8\,Ed_1}$ or $\dfrac{Pb_1}{6\,Ed_2}(3\,lb_1 - 4\,b_1^2)$
7. Load in terms of deflection, $\left\{\dfrac{8\,EId_1}{b_1b_2^2}\right.$ or $\dfrac{6\,EId_2}{b_1(3\,lb_1 - 4\,b_1^2)}$
8. Fiber stress in terms of deflection, $\left\{\dfrac{8\,Eyd_1}{b_2^2}\right.$ or $\dfrac{6\,Eyd_2}{(3\,lb_1 - 4\,b_1^2)}$
9. Greatest shear, from each end to support, P
10. Reactions.................. $U_1 = U_2 = P$



VI. Beam supported symmetrically, with two equal end loads.

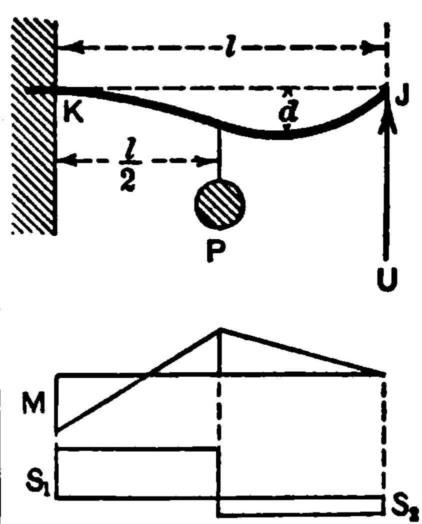
Properties of Solid and Tubular Beams (Continued)

1. Greatest bending moment, at K...... $\frac{Pb_1b_2}{l}$
2. Greatest fiber stress, at K... $\frac{Pb_1b_2y}{lI}$ or $\frac{Pb_1b_2}{lZ}$
3. Greatest safe load............ $\frac{flI}{b_1b_2y}$ or $\frac{flZ}{b_1b_2}$
4. Section modulus (Z)............... $\frac{Pb_1b_2}{fl}$
5. Greatest deflection $\left\{ \frac{Pb_1b_2}{27\,lEI}\sqrt{3\,b_2(2\,l-b_2)^3} \right.$ or $\frac{f}{27\,Ey}\sqrt{3\,b_2(2\,l-b_2)^3}$
6. Moment of inertia (I), $\frac{Pb_1b_2}{27\,l\,Ed}\sqrt{3\,b_2(2\,l-b_2)^3}$
7. Load in terms of deflection, $\frac{27\,l\,EId}{b_1b_2\sqrt{3\,b_2(2\,l-b_2)^3}}$
8. Fiber stress in terms of defl. $\frac{27\,Eyd}{\sqrt{3\,b_2(2\,l-b_2)^3}}$
9. Greatest shear, from J_1 to K.......... $\frac{Pb_2}{l}$
10. Reactions............ $U_1=\frac{Pb_2}{l}$ $U_2=\frac{Pb_1}{l}$



VII. Beam supported at both ends and loaded at any point of its length.

1. Greatest bending moment, at K...... $\frac{3}{16}Pl$
2. Greatest fiber stress, at K.... $\frac{3\,Ply}{16\,I}$ or $\frac{3\,Pl}{16\,Z}$
3. Greatest safe load.......... $\frac{16\,fI}{3\,ly}$ or $\frac{16\,fZ}{3\,l}$
4. Section modulus (Z)............... $\frac{3\,Pl}{16\,f}$
5. Greatest deflection...... $\frac{Pl^3\sqrt{5}}{240\,EI}$ or $\frac{fl^2\sqrt{5}}{45\,Ey}$
6. Moment of inertia (I)............ $\frac{Pl^3\sqrt{5}}{240\,Ed}$
7. Load in terms of deflection....... $\frac{240\,EI}{l^3\sqrt{5}}\,d$
8. Fiber stress in terms of deflection, $\frac{9\sqrt{5}\,Ey}{l^2}\,d$
9. Greatest shear, at K............... $\frac{11}{16}P$
10. Reaction.................... $U=\frac{5}{16}P$



VIII. Beam fixed at one end, supported at the other, and loaded at the middle.

Properties of Solid and Tubular Beams (Continued)

1. Greatest bending moment, at K, $Pb_1b_2\,\dfrac{l+b_2}{2\,l^2}$

2. Greatest fiber stress at K, $\left\{\dfrac{Pb_1b_2y(l+b_2)}{2\,l^2I}\right.$ or $\dfrac{Pb_1b_2(l+b_2)}{2\,l^2Z}$

3. Greatest safe load, $\dfrac{2\,l^2fI}{b_1b_2y(l+b_2)}$ or $\dfrac{2\,l^2fZ}{b_1b_2(l+b_2)}$

4. Section modulus (Z)......... $\dfrac{Pb_1b_2(l+b_2)}{2\,l^2f}$

5. Greatest deflection, $\dfrac{Pb_1^2b_2}{6\,EI}\sqrt{\dfrac{b_2}{2\,l+b_2}}$ or $\dfrac{b_1l^2f}{3\,Ey(l+b_2)}\sqrt{\dfrac{b_2}{2\,l+b_2}}$

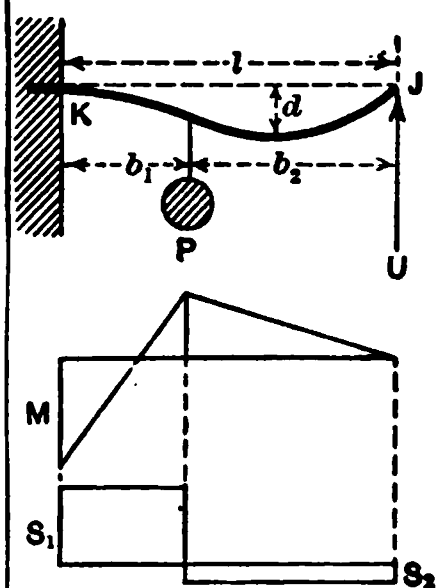
6. Moment of inertia (I).... $\dfrac{Pb_1^2b_2}{6\,Ed}\sqrt{\dfrac{b_2}{2\,l+b_2}}$

7. Load in terms of deflection.. $\dfrac{6\,EId}{b_1^2b_2\sqrt{\dfrac{b_2}{2\,l+b_2}}}$

8. Fiber stress in terms of defl., $\dfrac{3\,Ey(l+b_2)\,d}{b_1l^2\sqrt{\dfrac{b_2}{2\,l+b_2}}}$

9. Greatest shear from K to load, $\dfrac{P}{2\,l^3}(b_2^3-3\,b_2l^2)$

10. Reaction........ $U=\dfrac{P}{2\,l^3}(2\,l^3-3\,b_2l^2+b_2^3)$



IX. Beam fixed at one end, supported at the other, and loaded at any point of its length.

---

1. Greatest bending moment, at K....... $\dfrac{Wl}{8}$

2. Greatest fiber stress, at K..... $\dfrac{Wly}{8\,I}$ or $\dfrac{Wl}{8\,Z}$

3. Greatest safe load............ $\dfrac{8\,fI}{ly}$ or $\dfrac{8\,fZ}{l}$

4. Section modulus (Z)................ $\dfrac{Wl}{8\,f}$

5. Greatest deflection... $.0054\,\dfrac{Wl^3}{EI}$ or $.0432\,\dfrac{l^2f}{Ey}$

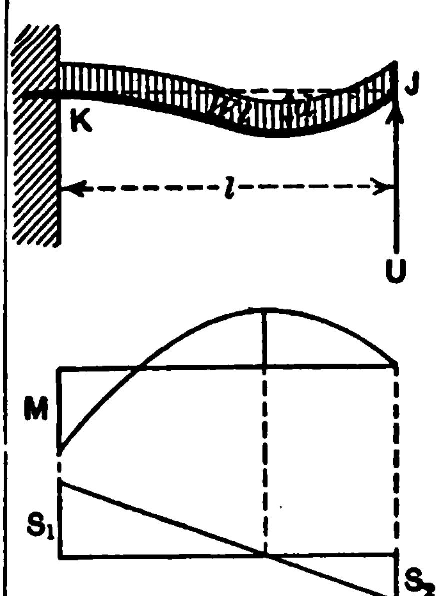
6. Moment of inertia (I)........... $.0054\,\dfrac{Wl^3}{Ed}$

7. Load in terms of deflection....... $185.2\,\dfrac{EId}{l^3}$

8. Fiber stress in terms of deflection.. $23.15\,\dfrac{Eyd}{l^2}$

9. Greatest shear, at K................ $\frac{5}{8}\,Wl$

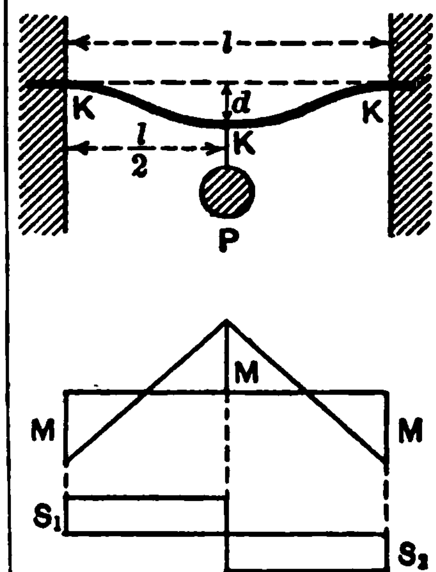
10. Reaction.................... $U=\frac{3}{8}\,Wl$



X. Beam fixed at one end, supported at the other, and uniformly loaded.

Properties of Solid and Tubular Beams (Concluded)

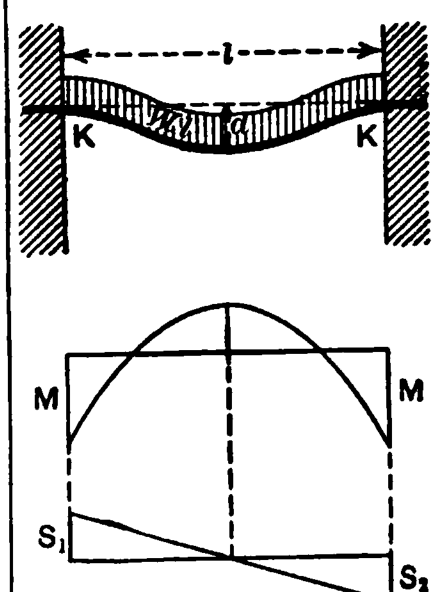
1. Greatest bending moment, at K........ $\frac{Pl}{8}$
2. Greatest fiber stress, at K....... $\frac{Ply}{8I}$ or $\frac{Pl}{8Z}$
3. Greatest safe load............. $\frac{8fI}{ly}$ or $\frac{8fZ}{l}$
4. Section modulus (Z)................. $\frac{Pl}{8f}$
5. Greatest deflection....... $\frac{Pl^3}{192\,EI}$ or $\frac{fl^2}{24\,Ey}$
6. Moment of inertia (I)............. $\frac{Pl^3}{192\,Ed}$
7. Load in terms of deflection........ $\frac{192\,EI}{l^3}d$
8. Fiber stress in terms of deflection... $\frac{24\,Ey}{l^2}d$
9. Greatest shear, K to K.............. $\frac{1}{2}P$



XI. Beam fixed at both ends and loaded at the middle.

---

1. Greatest bending moment, at K....... $\frac{Wl^2}{12}$
2. Greatest fiber stress, at K..... $\frac{Wl^2y}{12\,I}$ or $\frac{Wl^2}{12\,Z}$
3. Greatest safe load........... $\frac{12\,fI}{ly}$ or $\frac{12\,fZ}{l}$
4. Section modulus (Z)................ $\frac{Wl^2}{12\,f}$
5. Greatest deflection........ $\frac{Wl^4}{384\,EI}$ or $\frac{l^2f}{32\,Ey}$
6. Moment of inertia (I)............. $\frac{Wl^4}{384\,Ed}$
7. Load in terms of deflection....... $\frac{384\,EI}{l^3}d$
8. Fiber stress in terms of deflection... $\frac{32\,Ey}{l^2}d$
9. Greatest shear, at K................ $\frac{1}{2}Wl$

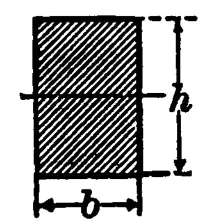


XII. Beam fixed at both ends and uniformly loaded.

Properties of Beam and Column Sections

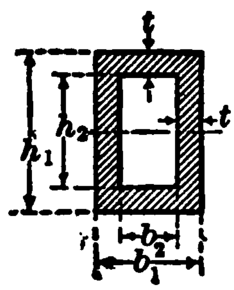
A = Area of Section.
W = Weight in pounds per foot, based on weight of cubic inch of steel = 0.2833 pound.
I = Moment of Inertia.
Z = Section Modulus.
R = Radius of Gyration.

1



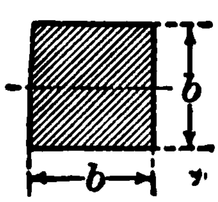
$$A = bh$$
$$W = 3.4\,bh$$
$$I = \tfrac{1}{12}\,bh^3$$
$$Z = \tfrac{1}{6}\,bh^2$$
$$R = 0.2887\,h$$

2



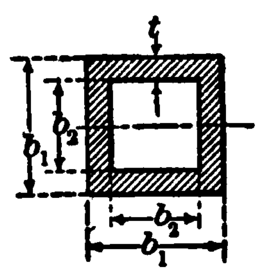
$$A = b_1h_1 - b_2h_2 = 2(b_1 + h_1 - 2\,t)\,t$$
$$W = 3.4(b_1h_1 - b_2h_2) = 6.8(b_1 + h_1 - 2\,t)\,t$$
$$I = \tfrac{1}{12}(b_1h_1^3 - b_2h_2^3)$$
$$Z = \frac{b_1h_1^3 - b_2h_2^3}{6\,h_1}$$
$$R = \sqrt{I \div A}$$

3



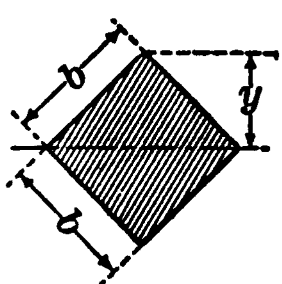
$$A = b^2$$
$$W = 3.4\,b^2$$
$$I = \tfrac{1}{12}\,b^4$$
$$Z = \tfrac{1}{6}\,b^3$$
$$R = 0.2887\,b$$

4



$$A = b_1^2 - b_2^2 = 4(b_1 - t)\,t$$
$$W = 3.4(b_1^2 - b_2^2) = 13.6(b_1 - t)\,t$$
$$I = \tfrac{1}{12}(b_1^4 - b_2^4)$$
$$Z = \tfrac{1}{6}\left(\frac{b_1^4 - b_2^4}{b_1}\right)$$
$$R = 0.2887\sqrt{b_1^2 + b_2^2}$$

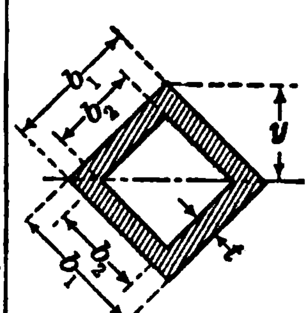
5



$y = 0.7071\,b$

$$A = b^2$$
$$W = 3.4\,b^2$$
$$I = \tfrac{1}{12}\,b^4$$
$$Z = 0.1179\,b^3$$
$$R = 0.2887\,b$$

6



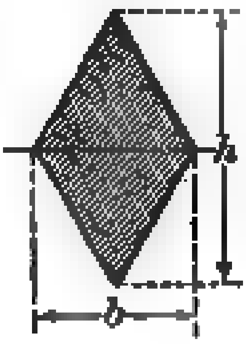
$y = 0.7071\,b_1$

$$A = b_1^2 - b_2^2 = 4(b_1 - t)\,t$$
$$W = 3.4(b_1^2 - b_2^2) = 13.6(b_1 - t)\,t$$
$$I = \tfrac{1}{12}(b_1^4 - b_2^4)$$
$$Z = 0.1179\left(\frac{b_1^4 - b_2^4}{b_1}\right)$$
$$R = 0.2887\sqrt{b_1^2 + b_2^2}$$

Properties of Beam and Column Sections (Continued)

A = Area of Section.
W = Weight in pounds per foot, based on weight of cubic inch of steel = 0.2833 pound.
I = Moment of Inertia.
Z = Section Modulus.
R = Radius of Gyration.

7



$A = \frac{1}{2}\, bh$

$W = 1.7\, bh$

$I = \frac{1}{48}\, bh^3$

$Z = \frac{1}{24}\, bh^2$

$R = 0.2041\, h$

8

$A = \frac{1}{2}(b_1h_1 - b_2h_2)$

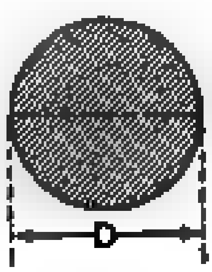
$W = 1.7(b_1h_1 - b_2h_2)$

$I = \frac{1}{48}(b_1h_1^3 - b_2h_2^3)$

$Z = \dfrac{b_1h_1^3 - b_2h_2^3}{24\, h_1}$

$R = \sqrt{I \div A}$

9



$A = 0.7854\, D^2$

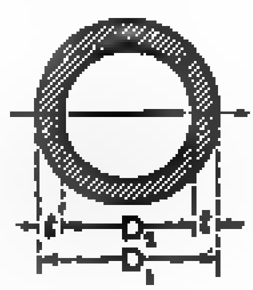
$W = 2.670\, D^2$

$I = 0.0491\, D^4$

$Z = 0.0982\, D^3$

$R = \frac{1}{4}\, D$

10



$A = 0.7854(D_1^2 - D_2^2)$
$\quad = 3.1416(D_1 - t)\, t$

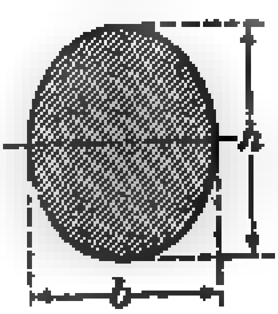
$W = 2.670(D_1^2 - D_2^2)$
$\quad = 10.68(D_1 - t)\, t$

$I = 0.0491\,(D_1^4 - D_2^4)$

$Z = 0.0982\left(\dfrac{D_1^4 - D_2^4}{D_1}\right)$

$R = \frac{1}{4}\sqrt{D_1^2 + D_2^2}$

11



$A = 0.7854\, bh$

$W = 2.670\, bh$

$I = 0.0491\, bh^3$

$Z = 0.0982\, bh^2$

$R = \frac{1}{4}\, h$

12

$A = 0.7854(b_1h_1 - b_2h_2)$
$\quad = 1.5708(b_1 + h_1 - 2\, t)\, t$

$W = 2.670(b_1h_1 - b_2h_2)$
$\quad = 5.340(b_1 + h_1 - 2\, t)\, t$

$I = 0.0491\,(b_1h_1^3 - b_2h_2^3)$

$Z = 0.0982\left(\dfrac{b_1h_1^3 - b_2h_2^3}{h_1}\right)$

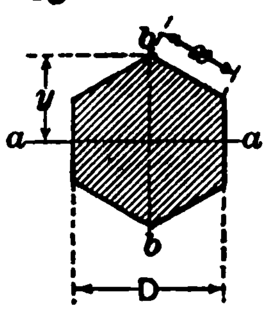
$R = \sqrt{I \div A}$

Properties of Beam and Column Sections (Continued)

A = Area of Section.
W = Weight in pounds per foot, based on weight of cubic inch of steel = 0.2833 pound.
I = Moment of Inertia.
Z = Section Modulus.
R = Radius of Gyration.

Note that position of axis through center of these sections affects the Section Modulus only.

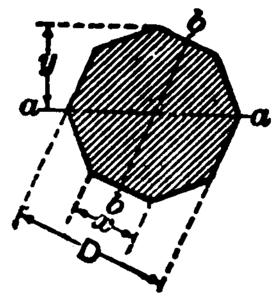
13



$A = 0.866\,D^2$
$W = 2.944\,D^2$
$I = 0.0601\,D^4$
$R = 0.2635\,D$
$Z_{aa} = 0.1042\,D^3$
$Z_{bb} = 0.1203\,D^3$

$y = x = 0.5774\,D$

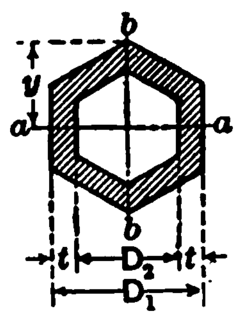
16



$A = 0.8284\,D^2$
$W = 2.816\,D^2$
$I = 0.0547\,D^4$
$R = 0.257\,D$
$Z_{aa} = 0.1011\,D^3$
$Z_{bb} = 0.1095\,D^3$

$x = 0.4142\,D$
$y = 0.5412\,D$

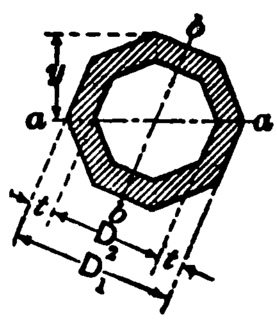
14



$A = 0.866(D_1^2 - D_2^2) = 3.464(D_1 - t)\,t$
$W = 2.944(D_1^2 - D_2^2) = 11.777(D_1 - t)\,t$
$I = 0.0601\,(D_1^4 - D_2^4)$
$R = 0.2635\sqrt{D_1^2 + D_2^2}$
$Z_{aa} = 0.1042\left(\dfrac{D_1^4 - D_2^4}{D_1}\right)$
$Z_{bb} = 0.1203\left(\dfrac{D_1^4 - D_2^4}{D_1}\right)$

$y = 0.5774\,D_1$

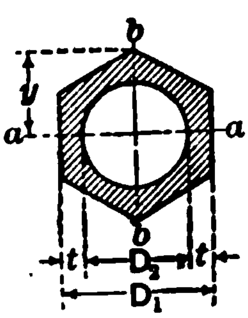
17



$A = 0.8284\,(D_1^2 - D_2^2) = 3.314(D_1 - t)\,t$
$W = 2.816\,(D_1^2 - D_2^2) = 11.265(D_1 - t)\,t$
$I = 0.0547\,(D_1^4 - D_2^4)$
$R = 0.257\sqrt{D_1^2 + D_2^2}$
$Z_{aa} = 0.1011\left(\dfrac{D_1^4 - D_2^4}{D_1}\right)$
$Z_{bb} = 0.1095\left(\dfrac{D_1^4 - D_2^4}{D_1}\right)$

$y = 0.5412\,D_1$

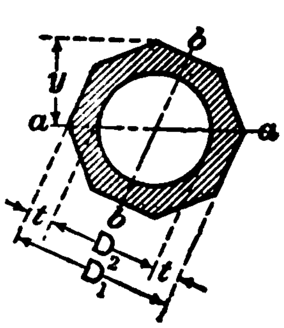
15



$A = 0.866\,D_1^2 - 0.7854\,D_2^2 = 0.0806\,D_1^2 + 3.1416(D_1 - t)t$
$W = 2.944\,D_1^2 - 2.670\,D_2^2 = 0.2741\,D_1^2 + 10.68(D_1 - t)\,t$
$I = 0.0601\,D_1^4 - 0.0491\,D_2^4$
$R = \sqrt{I \div A}$
$Z_{aa} = 0.1042\,D_1^3 - 0.085\left(\dfrac{D_2^4}{D_1}\right)$
$Z_{bb} = 0.1203\,D_1^3 - 0.0982\left(\dfrac{D_2^4}{D_1}\right)$

$y = 0.5774\,D_1$

18



$A = 0.8284\,D_1^2 - 0.7854\,D_2^2 = 0.0430\,D_1^2 + 3.1416(D_1 - t)t$
$W = 2.816\,D_1^2 - 2.670\,D_2^2 = 0.1463\,D_1^2 + 10.68(D_1 - t)t$
$I = 0.0547\,D_1^4 - 0.0491\,D_2^4$
$R = \sqrt{I \div A}$
$Z_{aa} = 0.1011\,D_1^3 - 0.0907\left(\dfrac{D_2^4}{D_1}\right)$
$Z_{bb} = 0.1095\,D_1^3 - 0.0982\left(\dfrac{D_2^4}{D_1}\right)$

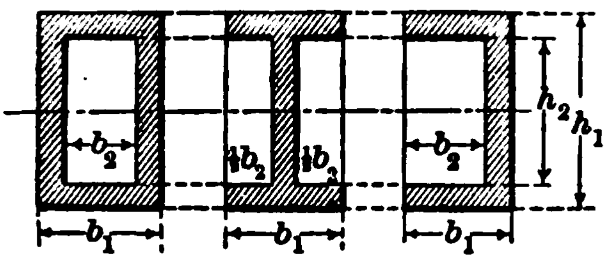
$y = 0.5412\,D_1$

Properties of Beam and Column Sections (Concluded)

A = Area of Section. I = Moment of Inertia.

R = Radius of Gyration. Z = Section Modulus.

19 20 21



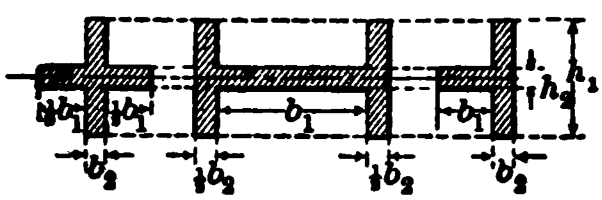
$$A = b_1h_1 - b_2h_2$$

$$I = \frac{1}{12}(b_1h_1^3 - b_2h_2^3)$$

$$Z = \frac{b_1h_1^3 - b_2h_2^3}{6\,h_1}$$

$$R = \sqrt{I \div A}$$

22 23 24



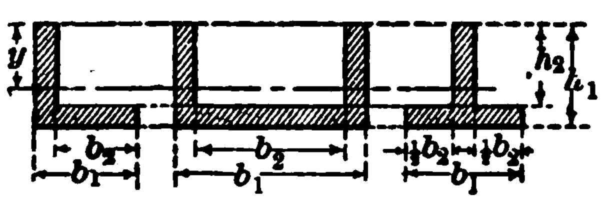
$$A = b_2h_1 + b_1h_2$$

$$I = \frac{1}{12}(b_2h_1^3 + b_1h_2^3)$$

$$Z = \frac{b_2h_1^3 + b_1h_2^3}{6\,h_1}$$

$$R = \sqrt{I \div A}$$

25 26 27



$$y = \frac{b_1h_1^2 - b_2h_2^2}{2\,(b_1h_1 - b_2h_2)}$$

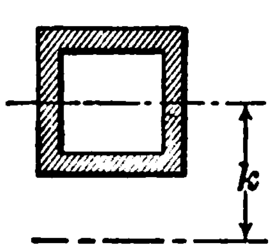
$$A = b_1h_1 - b_2h_2$$

$$I = \frac{(b_1h_1^2 - b_2h_2^2)^2 - 4\,b_1h_1b_2h_2(h_1 - h_2)^2}{12\,(b_1h_1 - b_2h_2)}$$

$$Z = \frac{(b_1h_1^2 - b_2h_2^2)^2 - 4\,b_1h_1b_2h_2(h_1 - h_2)^2}{6\,(b_1h_1^2 - b_2h_2^2)}$$

$$R = \sqrt{I \div A}$$

28



Let I be the Moment of Inertia of a cross-section with respect to an axis through its center of gravity, and I_1 the corresponding moment with respect to a parallel axis at a distance k from the first.

Also let A be the area of cross-section.

Then $I_1 = I + Ak^2$.

SAFETY FACTORS AND SAFE WORKING FIBER STRESSES

Each member of a mechanical structure should be capable of resisting the greatest straining action to which it can ordinarily be subjected when in use. The designer should, therefore, consider under what conditions the straining actions are greatest. When these actions are of a variable character, it is of the utmost importance to take into consideration the effects of this variation upon the endurance of the material. For example, a member may fail under a straining action that causes stresses which fluctuate, or which alternate repeatedly from tension to compression, when the same straining action would be successfully resisted under the conditions of steady loading.

Margin of Security. It is apparent that the working load on a member of a mechanical structure should be less than the calculated breaking load for that member, in order to allow for inaccuracies, deterioration, and probable contingencies, and thus provide a margin of security. It is customary, therefore, to design a member so that either (1) the statical breaking load, or (2) the load that causes the most strained fiber of the material to just reach its elastic limit, shall be a number of times the working load. This number is called the *safety factor*. Thus, in the first case, if the statical breaking strength were 12 000 pounds and the working load upon it 2000 pounds, then the safety factor would be 12 000 divided by 2000, or 6. In the second case, if the statical load that causes the most strained fiber of the member to just reach the elastic limit of the material were 6000 pounds and the working load upon it 2000 pounds, then the safety factor on this basis would be 3.

The elastic and ultimate strengths of the materials under static loading can be easily obtained. The strength, therefore, under an assumed steady loading, of any member of a mechanical structure can ordinarily be calculated with sufficient accuracy. But the proper safety factor to use under a given set of actual working conditions, involving actions of a more or less variable or uncertain character, can be arrived at in most cases only as the result of long experience, or by tedious experiment.

Safety Factor for Static Loading. For static loading, which can be estimated with a reasonable degree of exactness, a safety factor of 2, as based upon the elastic limit of the material, will ordinarily be found sufficient. By "static loading" is here meant one that causes a permanent and unvarying straining action.

Safety Factors for Variable Loading. In the absence of more precise data, the following formula, based upon the notable tests on the fatigue of steel under repeated loading, by Wohler and Spangenberg, and the later tests by Bauschinger and at the Watertown Arsenal, may

be used in finding the proper safety factor to use for variable loading of an indefinite number of repetitions:

$$F_2 = \left(2 - \frac{P_2}{P_1}\right)F_1. \tag{1}$$

Or, assuming a safety factor of 2 for static loading, as based upon the elastic limit of the material,

$$F_2 = 4 - \frac{2\,P_2}{P_1}, \tag{2}$$

where F_1 = safety factor under static loading;

F_2 = corresponding safety factor under a loading that varies repeatedly between the limits P_1 and P_2;

P_1 = greatest pressure due to the variable loading, to be taken as plus (+) if causing tension, and minus (−) if causing compression in the most strained fiber of the member;

P_2 = least pressure due to the variable loading, to be taken as plus (+) if causing tension, and minus (−) if causing compression in the most strained fiber of the member.

This formula is general in its application to an indefinitely great number of repetitions of loading with a known variation of stress. When the loading is of such a character as to cause the stress on the most strained fiber to alternate from tension to compression, care must be taken to give to P_1 and P_2 their proper algebraic signs. When P_2 is zero, or when the variable stress on the most strained fiber is either constantly tension or compression, then the algebraic signs of P_1 and P_2 will be the same and may therefore be ignored.

The following special cases are of frequent occurrence:

1. For a loading that causes an indefinite number of reversals of stress, that is to say, when the alternating tension and compression on the most strained fiber of a member are equal, then $P_2 = -P_1$ and equation (1) becomes

$$F_2 = \left(2 - \frac{-P_1}{P_1}\right)F_1 = (2 + 1)F_1 = 3\,F_1. \tag{3}$$

Or, assuming a safety factor of 2 for static loading, as based upon the elastic limit of the material,

$$F_2 = 6. \tag{4}$$

This shows for sudden reversals of stress, indefinitely repeated between equal limits of tension and compression, that the safety factor used should be three times that for static loading under otherwise similar conditions.

2. For a loading that causes stresses that alternate indefinitely between zero and a fixed value, $P_2 = 0$, and equation (1) becomes

$$F_2 = \left(2 - \frac{0}{P_1}\right)F_1 = (2 - 0)F_1 = 2\,F_1. \tag{5}$$

Or, assuming a safety factor of 2 for static loading, as based upon the elastic limit of the material,

$$F_2 = 4. \tag{6}$$

This shows, for a suddenly applied loading indefinitely repeated, that the safety factor used should be twice that for static loading under otherwise similar conditions.

3. For a steadily applied loading P_2 will of course equal P_1, and equation (1) becomes $F_2 = (2 - 1) F_1 = F_1$ which shows that formula (1) is correct at its inferior limit.

Safe Working Fiber Stresses. Since for any given material the working fiber stresses for the different conditions of variable loading are inversely proportional to the corresponding safety factors, it is apparent that formula (1) may be put into the following form:

$$f_2 = \frac{f_1}{2 - \frac{P_2}{P_1}}, \tag{7}$$

where, in addition to the notation as used above, f_1 = working fiber stress under static loading, in pounds per square inch, and f_2 = corresponding working fiber stress under a loading that varies repeatedly between the limits P_1 and P_2.

This formula is general in its application, care being taken to give to P_1 and P_2 their proper algebraic signs, as fully explained in connection with formula (1) above.

The following are important special cases of this formula:

1. For a loading that causes an indefinite number of reversals of stress, the alternating tension and compression on the most strained fiber being equal, $P_2 = -P_1$, and equation (7) becomes

$$f_2 = \frac{f_1}{2 + 1} = \frac{1}{3} f_1. \tag{8}$$

Or, the safe working fiber stress under this condition is one-third of that under similar static loading.

2. For a loading that causes stresses that alternate indefinitely between zero and a fixed value, whether tension or compression, $P_2 = 0$, and equation (7) becomes

$$f_2 = \frac{f_1}{2 - 0} = \frac{1}{2} f_1. \tag{9}$$

Or, the safe working fiber stress under this condition is one-half of that under similar static loading.

WATER

Properties

WATER

Water is composed of two gases, hydrogen and oxygen, in the ratio of two volumes of the former to one of the latter. It is never found pure in nature, owing to the readiness with which it absorbs impurities from the air and soil. Water boils under atmospheric pressure (14.7 pounds at sea level) at 212°, passing off as steam. Its greatest density is at 39.1° F., when it weighs 62.425 pounds per cubic foot.

Weight of Water per Cubic Foot at Different Temperatures

Temperature °F.	Weight per cubic foot, pounds	Temperature °F.	Weight per cubic foot, pounds	Temperature °F.	Weight per cubic foot, pounds	Temperature °F.	Weight per cubic foot, pounds	Temperature °F.	Weight per cubic foot, pounds
32	62.42	150	61.18	260	58.55	380	54.36	500	48.7
40	62.42	160	60.98	270	58.26	390	53.94	510	48.1
50	62.41	170	60.77	280	57.96	400	53.5	520	47.6
60	62.37	180	60.55	290	57.65	410	53.0	530	47.0
70	62.31	190	60.32	300	57.33	420	52.6	540	46.3
80	62.23	200	60.12	310	57.00	430	52.2	550	45.6
90	62.13	210	59.88	320	56.66	440	51.7	560	44.9
100	62.02	212	59.83	330	56.30	450	51.2	570	44.1
110	61.89	220	59.63	340	55.94	460	50.7	580	43.3
120	61.74	230	59.37	350	55.57	470	50.2	590	42.6
130	61.56	240	59.11	360	55.18	480	49.7	600	41.8
140	61.37	250	58.83	370	54.78	490	49.2		

Volume of Water

Cent.	Fahr.	Volume	Cent.	Fahr.	Volume	Cent.	Fahr.	Volume
4°	39.1°	1.00000	35°	95°	1.00586	70°	158°	1.02241
5	41	1.00001	40	104	1.00767	75	167	1.02548
10	50	1.00025	45	113	1.00967	80	176	1.02872
15	59	1.00083	50	122	1.01186	85	185	1.03213
20	68	1.00171	55	131	1.01423	90	194	1.03570
25	77	1.00286	60	140	1.01678	95	203	1.03943
30	86	1.00425	65	149	1.01951	100	212	1.04332

WATER PRESSURE

(From Kent's Mechanical Engineers' Pocket Book.)

Comparison of Heads of Water in Feet with Pressures in Various Units

One foot of water at 39.1° F. = 62.425 pounds per square foot;
One foot of water at 39.1° F. = 0.4335 pound per square inch;
One foot of water at 39.1° F. = 0.0295 atmosphere;
One foot of water at 39.1° F. = 0.8826 inch of mercury at 30° F.;
One foot of water at 39.1° F. = 773.3 { feet of air at 32° F. and atmospheric pressure;
One pound on the square foot, at 39.1° F. = 0.01602 foot of water;
One pound on the square inch, at 39.1° F. = 2.307 feet of water;
One atmosphere of 29.922 inches of mercury = 33.9 feet of water;
One inch of mercury at 32° F. .... = 1.133 feet of water;
One foot of air at 32° F. and 1 atmosphere = 0.001293 foot of water;
One foot of average sea-water .... = 1.026 feet of pure water;
One foot of water at 62° F. .... = 62.355 pounds per square foot;
One foot of water at 62° F. .... = 0.43302 pound per square inch;
One inch of water at 62° F. = 0.5774 ounce = 0.036085 pound per square inch;
One pound of water on the square inch at 62° F. .... = 2.3094 feet of water;
One ounce of water on the square inch at 62° F. .... = 1.732 inches of water.

Pressure of Water Due to Its Weight. The pressure of still water in pounds per square inch against the sides of any pipe, channel, or vessel of any shape whatever is due solely to the "head" or height of the level surface of the water above the point at which the pressure is considered, and is equal to 0.43302 pound per square inch for every foot of head, or 62.355 pounds per square foot for every foot of head (at 62° F.).

The pressure per square inch is equal in all directions, downwards, upwards, or sideways, and is independent of the shape or size of the containing vessel.

The pressure against a vertical surface, as a retaining-wall, at any point, is in direct ratio to the head above that point, increasing from 0 at the level surface, to a maximum at the bottom. The total pressure against a vertical strip of a unit's breadth increases as the area of a right-angled triangle whose perpendicular represents the height of the strip and whose base represents the pressure on a unit of surface at the bottom; that is, it increases as the square of the depth. The sum of all the horizontal pressures is represented by the area of the triangle, and the resultant of this sum is equal to this sum exerted at a point one-third of the height from the bottom. (The center of gravity of the area of a triangle is one-third of its height.)

The horizontal pressure is the same if the surface is inclined instead of vertical.

The amount of pressure on the interior walls of a pipe has no appreciable effect upon the amount of flow.

Pressure in Pounds per Square Inch for Different Heads of Water

(At 62° F., 1 foot head = 0.433 pound per square inch; 0.433 × 144 = 62.352 pounds per cubic foot.)

Head, feet	0	1	2	3	4	5	6	7	8	9
0	......	0.433	0.866	1.299	1.732	2.165	2.598	3.031	3.464	3.897
10	4.330	4.763	5.196	5.629	6.062	6.495	6.928	7.361	7.794	8.227
20	8.660	9.093	9.526	9.959	10.392	10.825	11.258	11.691	12.124	12.557
30	12.990	13.423	13.856	14.289	14.722	15.155	15.588	16.021	16.454	16.887
40	17.320	17.753	18.186	18.619	19.052	19.485	19.918	20.351	20.784	21.217
50	21.650	22.083	22.516	22.949	23.382	23.815	24.248	24.681	25.114	25.547
60	25.980	26.413	26.846	27.279	27.712	28.145	28.578	29.011	29.444	29.877
70	30.310	30.743	31.176	31.609	32.042	32.475	32.908	33.341	33.774	34.207
80	34.640	35.073	35.506	35.939	36.372	36.805	37.238	37.671	38.104	38.537
90	38.970	39.403	39.836	40.269	40.702	41.135	41.568	42.001	42.434	42.867

Head in Feet of Water, Corresponding to Pressures in Pounds per Square Inch

(1 pound per square inch = 2.30947 feet head; 1 atmosphere = 14.7 pounds per square inch = 33.94 feet head.)

Pressure, lbs.	0	1	2	3	4	5	6	7	8	9
0	....	2.309	4.619	6.928	9.238	11.547	13.857	16.166	18.476	20.785
10	23.0947	25.404	27.714	30.023	32.333	34.642	36.952	39.261	41.570	43.880
20	46.1894	48.499	50.808	53.118	55.427	57.737	60.046	62.356	64.665	66.975
30	69.2841	71.594	73.903	76.213	78.522	80.831	83.141	85.450	87.760	90.069
40	92.3788	94.688	96.998	99.307	101.62	103.93	106.24	108.55	110.85	113.16
50	115.4735	117.78	120.09	122.40	124.71	127.02	129.33	131.64	133.95	136.26
60	138.5682	140.88	143.19	145.50	147.81	150.12	152.42	154.73	157.04	159 35
70	161.6629	163.97	166.28	168.59	170.90	173.21	175.52	177.83	180.14	182.45
80	184.7576	187.07	189.38	191.69	194.00	196.31	198.61	200.92	203.23	205.54
90	207.8523	210.16	212.47	214.78	217.09	219.40	221.71	224.02	226.33	228.64

Ice and Snow. (From Clark.) 1 cubic foot of ice at 32° F. weighs 57.50 pounds; 1 pound of ice at 32° F. has a volume of 0.0174 cubic foot = 30.067 cubic inches.

Relative volume of ice to water at 32° F., 1.0855, the expansion in passing into the solid state being 8.55 per cent. Specific gravity of ice = 0.922, water at 62° F. being 1.

At high pressures the melting-point of ice is lower than 32° F., being at the rate of 0.0133° F. for each additional atmosphere of pressure.

Specific heat of ice is 0.504, that of water being 1.

1 cubic foot of fresh snow, according to humidity of atmosphere, weighs 5 pounds to 12 pounds. 1 cubic foot of snow moistened and compacted by rain weighs 15 pounds to 50 pounds (Trautwine).

Specific Heat of Water

(From Marks and Davis's Steam Tables.)

Degrees F.	Specific heat	Degrees F.	Specific heat	Degrees F.	Specific heat	Degrees F.	Specific heat	Degrees F.	Specific heat	Degrees F.	Specific heat
20	1.0168	120	0.9974	220	1.007	320	1.035	420	1.072	520	1.123
30	1.0098	130	0.9979	230	1.009	330	1.038	430	1.077	530	1.128
40	1.0045	140	0.9986	240	1.012	340	1.041	440	1.082	540	1.134
50	1.0012	150	0.9994	250	1.015	350	1.045	450	1.086	550	1.140
60	0.9990	160	1.0002	260	1.018	360	1.048	460	1.091	560	1.146
70	0.9977	170	1.0010	270	1.021	370	1.052	470	1.096	570	1.152
80	0.9970	180	1.0019	280	1.023	380	1.056	480	1.101	580	1.158
90	0.9967	190	1.0029	290	1.026	390	1.060	490	1.106	590	1.165
100	0.9967	200	1.0039	300	1.029	400	1.064	500	1.112	600	1.172
110	0.9970	210	1.0050	310	1.032	410	1.068	510	1.117		

Compressibility of Water. Water is very slightly compressible. Its compressibility is from 0.000040 to 0.000051 for one atmosphere, decreasing with increase of temperature. For each foot of pressure, distilled water will be diminished in volume 0.0000015 to 0.0000013. Water is so incompressible that even at a depth of a mile, a cubic foot of water will weigh only about half a pound more than at the surface.

BOILER INCRUSTATION AND CORROSION

Water, from natural sources, as a rule contains more or less carbon dioxide, which holds in solution carbonates of lime and magnesia. On boiling the water the carbon dioxide is driven out, and the lime and magnesium in solution are thrown down in the form of a white or grayish mud, that may be easily removed from the boiler by thorough washing. The presence of other impurities, such as organic matter or sulphate of lime, is likely to make the deposit hard and adhering.

Sulphate of lime is more soluble in cold than in hot water, and is entirely thrown down at a temperature of 280° Fahrenheit. It forms a hard and adhering scale and has a bad effect upon scales and deposits, composed chiefly of carbonates. The bad effect of deposits from water containing calcium sulphate is much ameliorated by introducing carbonate of soda or soda-ash into the boiler with the feed-water. The result is to give a deposit of calcium carbonate in the form of a fine white powder, which must be washed or swept out, and sodium sulphate in solution, which must be blown out from time to time.

A deposition may arise from the settling of clay and other matter held in suspension in the water. In water otherwise free from impurities this matter commonly deposits in the form of a soft mud that may be easily removed from the boiler. In conjunction, however, with other impurities, as, for example, sulphate of lime, it may form an adhesive

scale, in which case it is usually best to free the feed-water from suspended matter by filtration.

In some cases chemical treatment, either internally or externally, should be resorted to. This is especially the case with feed-waters containing much free acid, in which case the free acid should be neutralized by chemical treatment, preferably before entering the boiler.

If more than 100 parts per 100 000 of total solid residue be present in the water, it will ordinarily cause trouble from scale, and should be condemned for use in the boiler unless a better supply be unobtainable. Scale reduces the efficiency of the heating surface by detracting from the conducting quality of the metal and is apt to cause overheating or burning of the metal, or even bulging of the plates that are subjected to the intense heat of the furnace. Grease, owing to its adhesive nature, may, by collecting impurities contained in the water, become sufficiently heavy to sink. In this condition it is apt to attach itself to a plate or pipe near the furnace, and may, owing to its nonconducting qualities, cause serious overheating, resulting in burning, bulging, or even blowing out.

If water contains more than 5 parts per 100 000 of free sulphuric or nitric acid, serious corrosion will ensue, not only in boiler plates, but also in tubes, pipes, cylinders and other parts with which the steam comes in contact.

Animal and vegetable oils and greases decompose into fatty acids when subjected to the temperature of high-pressure steam. Because of this their presence in a high-pressure steam engine or boiler will cause serious corrosion.

Tabular View

Troublesome substance	Trouble	Remedy or palliation
Sediment, mud, clay, etc.	Incrustation.	Filtration; blowing off.
Readily soluble salts.	Incrustation.	Blowing off.
Bicarbonates of lime, magnesia, iron.	Incrustation.	Heating feed. Addition of caustic soda, lime or magnesia, etc.
Sulphate of lime.	Incrustation.	Addition of carbonate of soda, barium chloride, etc.
Chloride and sulphate of magnesium.	Corrosion.	Addition of carbonate of soda, etc.
Carbonate of soda in large amounts.	Priming.	Addition of barium chloride, etc.
Acid (in mine waters).	Corrosion.	Alkali.
Dissolved carbonic acid and oxygen.	Corrosion.	Heating feed. Addition of caustic soda, slaked lime, etc.
Grease (from condensed steam).	Corrosion.	Slaked lime and filtering. Carbonate of soda. Substitute mineral oil.
Organic matter (sewage).	Corrosion.	Precipitate with alum or ferric chloride and filter.

Experiments have shown that pure water, into which air has been forced, on heating causes corrosion.

Highly heated surfaces in contact with water containing common salt corrode and pit rapidly. The sides of the furnace, the tube plates and the hottest tubes suffer most.

It is clear, then, that feed-water, free from solids, combined or in suspension, organic matter, acids of all kinds, and air, would be best for the life of boilers.

In cases where water containing large amounts of total solid residue is necessarily used, a heavy petroleum oil, free from tar or wax, which is not acted upon by acids or alkalies, not having sufficient wax in it to cause saponification, and which has a vaporizing-point at nearly 600° F., will give the best results in preventing boiler-scale. Its action is to form a thin, greasy film over the boiler linings, protecting them largely from the action of acids in the water and greasing the sediment which is formed, thus preventing the formation of scale and keeping the solid residue from the evaporation of the water in such a plastic suspended condition that it can be easily ejected from the boiler by the process of "blowing off." If the water is not blown off sufficiently often, this sediment forms into a "putty" that will necessitate cleaning the boilers.

Practical experience is decidedly in favor of water purification, both from the standpoint of preserving the life of the boiler and for the best efficiency in operation. Air in solution, if allowed to enter the boiler, will accelerate corrosion more than any other cause, hence water heaters should be used with open feed and careful regulation of the temperature, which should always be about 190° F.

FLOW OF WATER IN PIPES

The quantity of water discharged through a pipe depends on the head. If the discharge occurs freely into the air, this head is the difference in level between the surface of the water in the reservoir and the center of the discharge end of the pipe; if the lower end of the pipe is submerged, the head is the difference in elevation between the two water levels. The discharge for a given diameter depends also upon the length of the pipe, upon the character of its interior surface as to smoothness and upon the number and sharpness of its bends.

The head, instead of being an actual distance between levels, may be caused by pressure, as by pumping, in which case the head is calculated as a vertical distance corresponding to the pressure, 1 pound per square inch being equal to 2.309 feet head, or 1 foot head being equal to a pressure of 0.433 pound per square inch.

The total head operating to cause flow is divided into three parts: (1) The velocity head, which is the height through which a body must fall in a vacuum to acquire the velocity with which the water flows in the pipe. This is equal to $v^2 \div 2g$, in which v is the velocity in feet per second, and $2g = 64.32$; (2) The entry head, which is required to overcome the resistance to entrance to the pipe. With sharp-edged

entrance the entry head equals about one-half of the velocity head; with smooth, rounded entrance the entry head is inappreciable; (3) The friction head, due to the frictional resistance to flow in the pipe.

In ordinary cases of pipes of considerable length the sum of the entry and velocity heads scarcely exceeds one foot; in the case of long pipes with low heads it is so small that it may be neglected.

When the flow becomes steady, the pipe is entirely filled throughout its length, and hence the mean velocity at any section is the same as that at the end, when the size is uniform. This velocity is found to decrease as the length of the pipe increases, other things being equal, and becomes very small for great lengths, which shows that nearly all the head has been lost in overcoming the resistances. The length of the pipe is measured along its axis, following all the curves, if there be any. The velocity considered is the mean velocity, which is equal to the discharge divided by the area of the cross section of the pipe. The actual velocities in the cross section are greater than this mean velocity near the center and less than it near the interior surface of the pipe.

The object of the discussion of flow in pipes is to enable the discharge which will occur under given conditions to be determined, or to ascertain the proper size which a pipe should have in order to deliver a given discharge. The subject cannot, however, be developed with the definiteness which characterizes the flow from orifices and weirs, partly because the condition of the interior surface of the pipe greatly modifies the discharge, partly because of the lack of experimental data, and partly on account of defective theoretical knowledge regarding the laws of flow. In orifices and weirs errors of two or three per cent may be regarded as large with careful work; in pipes such errors are common, and are generally exceeded in most practical investigations.

It fortunately happens, however, that in most cases of the design of systems of pipes errors of five and ten per cent are not important, although they are of course to be avoided if possible, or, if not avoided, they should occur on the side of safety.

Quantity of Water Discharged

The quantity of water which flows through a pipe is the product of the area of its cross section and the mean velocity of flow. That is,

$$Q = av,$$

in which Q is the quantity discharged in cubic feet per second, a is the area in square feet and v is the velocity in feet per second.

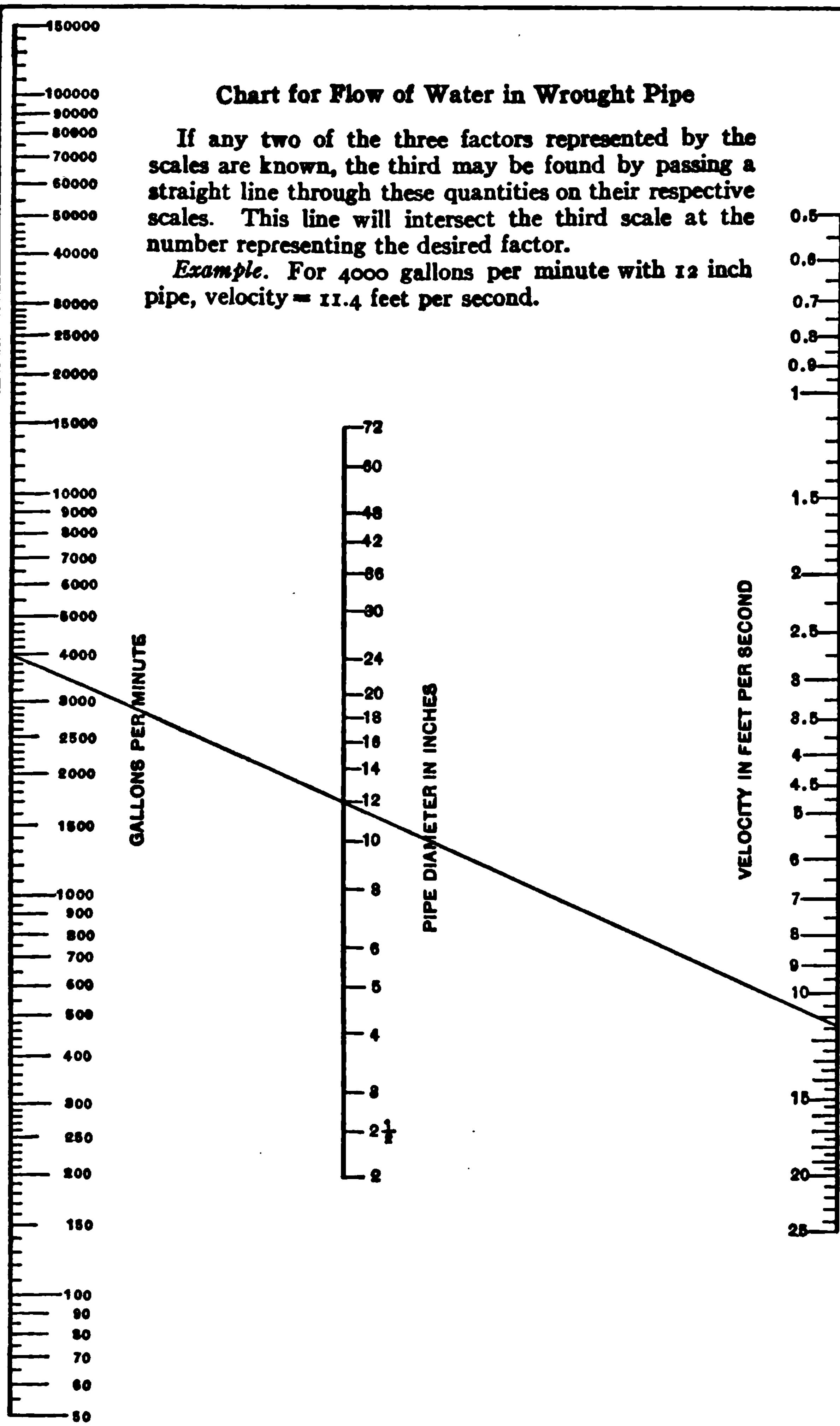
For U. S. gallons per second multiply by	7.4805
For U. S. gallons per minute multiply by	448.83
For U. S. gallons per hour multiply by	26929.9
For U. S. gallons per 24 hours multiply by	646317.

The diagram, page 279, gives the discharge in gallons per minute, when the velocity in the pipe line is known.

Chart for Flow of Water in Wrought Pipe

If any two of the three factors represented by the scales are known, the third may be found by passing a straight line through these quantities on their respective scales. This line will intersect the third scale at the number representing the desired factor.

Example. For 4000 gallons per minute with 12 inch pipe, velocity = 11.4 feet per second.



Mean Velocity of Flow

The velocity of flow, depending as it does to such a great extent upon the condition of the interior surface of the pipe, is difficult to compute. Below are given the formulæ most generally accepted. In the solution of any problem a comparison of the results obtained by the use of these formulæ is advisable. There are so many conditions affecting the flow of water that all hydraulic formulæ give only approximations to accurate results.

Approximate Formula (Trautwine). To find the velocity of water discharged from a pipe line, knowing the head, length and inside diameter, use the following formula:

$$v = m\sqrt{\frac{hD}{L + 54\,D}},$$

in which v = approximate mean velocity in feet per second;
m = coefficient from table below;
D = diameter of pipe in feet;
h = total head in feet;
L = total length of line in feet.

Values of Coefficient "m"

Diameter of pipe		m	Diameter of pipe		m
Feet	Inches		Feet	Inches	
0.1	1.2	23	1.5	18	53
0.2	2.4	30	2.0	24	57
0.3	3.6	34	2.5	30	60
0.4	4.8	37	3.0	36	62
0.5	6.0	39	3.5	42	64
0.6	7.2	42	4.0	48	66
0.7	8.4	44	5.0	60	68
0.8	9.6	46	6.0	72	70
0.9	10.8	47	7.0	84	72
1.0	12.0	48	10.0	120	77

The above coefficients are averages deduced from a large number of experiments. In most cases of pipes carefully laid and in fair condition, they should give results within 5 to 10 per cent of the truth.

Example: Given the head, $h = 50$ feet, the length, $L = 5280$ feet, and the diameter, $D = 2$ feet; to find the velocity and quantity of discharge.

The value of the coefficient m from the table when $D = 2$ feet is $m = 57$.

Substituting these values in the formula, we get:

$$v = 57\sqrt{\frac{50 \times 2}{5280 + 108}} = 57\sqrt{\frac{100}{5388}} = 57 \times 0.136 = 7.752 \text{ feet per sec.}$$

To find the discharge in cubic feet per second, multiply this velocity by the area of cross section of the pipe in square feet.

Thus, $3.1416 \times (1)^2 \times 7.752 = 24.35$ cubic feet per second.

Since there are 7.48 gallons in a cubic foot, the discharge in gallons per second $= 24.35 \times 7.48 = 182.1$.

The above formula is only an approximation, since the flow is modified by bends, joints, incrustations, etc. Wrought pipes are smoother than cast-iron ones, thereby presenting less friction and less encouragement for deposits; and, being in longer lengths, the number of joints is reduced, thus lessening the undesirable effects of eddy currents.

Kutter's Formula. This formula, although originally designed for open channels, can be used in the case of long pipes with low heads. It is the joint production of two eminent Swiss engineers, E. Ganguillet and W. R. Kutter, and is, properly speaking, a formula for finding the coefficient C in the well-known Chezy formula:

$$v = C\sqrt{rs},$$

in which

v = mean velocity in feet per second;
r = mean hydraulic radius in feet;
s = slope = head ÷ length, measured in a straight line from end to end.

The mean hydraulic radius is the area of wet cross-section divided by the wet perimeter, which for pipes running full, or exactly half full, is equal to one-quarter of the diameter.

According to Kutter the value of this coefficient C is

$$C = \frac{41.6 + \frac{0.00281}{s} + \frac{1.811}{n}}{1 + \left(41.6 + \frac{0.00281}{s}\right) \times \frac{n}{\sqrt{r}}},$$

in which s is the slope, r is the mean hydraulic radius in feet and n is the "coefficient of roughness." The value of n varies from .010 for very smooth pipes to .015 for pipes in a very poor condition. For ordinary wrought pipe .012 can be used. For clean steel riveted pipe .015 can be used.

The following table gives values of the coefficient C as obtained by Kutter's formula for different slopes, hydraulic radii and degrees of roughness.

Table of Coefficient "C"

Coefficient "n"	Hydraulic radius in r feet .1	.15	.2	.3	.4	.6	.8	1.0	1.5	2.0	3.0
	Slope $s=.0004$										
.009	104	116	126	138	148	157	166	172	183	190	199
.010	89	101	110	120	129	140	148	154	164	170	179
.011	78	90	97	107	115	126	133	138	148	154	162
.012	69	80	87	96	104	113	121	125	135	141	149
.013	62	71	78	87	94	103	110	115	124	130	138
.015	50	59	65	73	79	87	93	98	106	112	119
.017	43	50	54	62	68	75	81	85	93	98	105
	Slope $s=.0010$										
.009	110	121	129	141	150	161	169	175	184	191	199
.010	94	105	113	124	131	142	150	155	165	171	179
.011	83	92	99	109	117	127	134	139	149	155	163
.012	73	82	89	98	105	115	122	127	136	142	149
.013	65	74	81	89	96	104	111	116	124	130	138
.015	54	61	66	74	80	88	94	99	108	112	119
.017	45	51	57	63	69	76	82	86	93	98	105
	Slope $s=.0100$										
.009	110	122	130	143	151	162	170	175	185	191	199
.010	95	105	114	125	133	143	151	156	165	171	179
.011	83	93	100	111	119	129	135	141	149	155	162
.012	74	83	90	100	107	116	123	128	136	142	149
.013	66	75	81	90	98	106	112	117	125	130	138
.015	54	62	67	76	82	90	95	99	107	112	119
.017	46	52	57	64	70	77	82	87	94	99	105

For slopes steeper than .01 per unit of length, = 52.8 feet per mile, C remains practically the same as at that slope. But the velocity (being $C \times \sqrt{rs}$) of course continues to increase as the slope becomes steeper.

Darcy's Formula. The simplest form of Darcy's formula is

$$Cv^2 = Ds,$$

in which v is the velocity in feet per second, D is the diameter of the pipe in feet, s is the slope and C is a coefficient, varying with the diameter and roughness of the pipe. For cast-iron pipe and wrought pipes of the same roughness, the values of C are given below. For rough pipe Darcy doubled the coefficient.

Values of "C" in Darcy's Formula

Diameter, inches	Rough pipe	Smooth pipe
3	0.00080	0.00040
4	0.00076	0.00038
6	0.00072	0.00036
8	0.00068	0.00034
10	0.00066	0.00033
12	0.00066	0.00033
14	0.00065	0.000325
16	0.00064	0.00032
24	0.00064	0.00032
30	0.00063	0.000315
36	0.00062	0.00031
48	0.00062	0.00031

Williams and Hazen's Exponential Formula. From Chezy's formula, $v = C\sqrt{rs}$, it would appear that the velocity varies as the square root of the head; this is not true, however, for C is not a constant, but a variable depending upon the roughness of the pipe and upon the hydraulic radius and the slope. Hazen and Williams, as a result of a study of the best records of experiments and plotting them on logarithmic ruled paper, found an exponential formula $v = Cr^{0.63}s^{0.54}$, in which the coefficient C is practically independent of the diameter and the slope, and varies only with the condition of the surface. In order to equalize the numerical value of C to that of the C in the Chezy formula, at a slope of 0.001, they added the factor $0.001^{-0.04}$ to the formula, so that the working formula of Hazen and Williams is

$$v = Cr^{0.63}s^{0.54}0.001^{-0.04}.$$

The value of C varies to a great extent, depending on the condition of the interior of the pipe. A fair value for iron or steel pipe is $C = 100$. Computations of the exponential formula are made by logarithms or by the Hazen-Williams hydraulic slide rule.

Effect of Curves and Valves (American Civil Engineers' Pocket Book). The effect of curvature is to increase the loss of head. This increased loss is partly due to the cross currents and eddies set up in the bend, but also to the changes of velocity along the stream lines and increased friction along the walls of the channels, due to increased velocities over part of the circumference. The loss of head due to a curve may be stated in terms of the velocity head or, better, in terms of the equivalent length of straight pipe which would give the same loss as the curve. Experiments upon the loss of head in pipes show the radius of the curve of minimum resistance for a right-angled bend to be about three diameters of the pipe. For six-inch pipe the loss due to such a curve is about the same as that in eight feet of straight pipe, and for a thirty-inch pipe about the same as that in forty feet of straight

pipe. For intermediate sizes the loss may be expected to fall between these limits and to vary approximately as the diameter.

The losses due to valves in pipe lines have been investigated with accuracy in only a few instances. From these experiments it appears that a fully open gate valve in a pipe causes a loss of head corresponding to about six diameters of length of the pipe.

Hydraulic Grade-line. In a straight tube of uniform diameter throughout, running full and discharging freely into the air, the hydraulic grade-line is a straight line drawn from the discharge end to a point immediately over the entry end of the pipe, and at a depth below the surface equal to the entry and velocity heads (Trautwine).

In a pipe leading from a reservoir, no part of its length should be above the hydraulic grade-line.

Air-bound Pipes. A pipe is said to be air-bound when, in consequence of air being entrapped at the high points of vertical curves in the line, water will not flow out of the pipe, although the supply is higher than the outlet. The remedy is to provide cocks or valves at the high points, through which the air may be discharged. The valve may be made automatic by means of a float.

Water Hammer. When a valve in a pipe is closed while the water is flowing, the velocity of the water behind the valve is retarded and a dynamic pressure is produced. When the valve is closed quickly this dynamic pressure may be much greater than that due to the static pressure, and it is then called "water hammer" or "water ram." This action is dangerous and causes in many cases fracture of the pipe. It is provided against by arrangements which prevent a rapid closing of the valve. The formulæ for the pressure produced by this shock are

$$p = 0.027 \frac{lv}{t} - p_0 + p_1, \tag{1}$$

$$p = 63\,v - p_0 + p_1, \tag{2}$$

where p_0 = the static pressure when there is no flow, p_1 = the static pressure when the flow is in progress, p = the maximum dynamic pressure due to the water hammer in excess over the pressure p_0, v = the velocity in feet per second, l = length of pipe back from the valve in feet, and t = time of closing of valve in seconds. The pressures in the formulæ are expressed in pounds per square inch. Formula (1) is to be used when t is greater than $0.000428\,l$ and formula (2) when t is equal to or less than this.

From the first of these formulæ the value of t when $p = 0$ is found to be

$$t = 0.027 \frac{lv}{p_0 - p_1},$$

which is the time of valve closing in order that there may be no water hammer. To prevent the effects of water hammer, it is customary to arrange valves so that they cannot be closed very quickly, and the last formula furnishes the means of estimating the time required in order that no excess of dynamic pressure over the static pressure p_0 may occur.

Flow of Water in House-service Pipes

(Thomson Meter Company.)

Condition of discharge	Pressure in main, pounds per square inch	Discharge in cubic feet per minute								
		Nominal internal diameter of pipe (inches)								
		½	⅝	¾	1	1½	2	3	4	6
Through 35 feet of service pipe, no back pressure.	30	1.10	1.92	3.01	6.13	16.58	33.34	88.16	173.85	444.63
	40	1.27	2.22	3.48	7.08	19.14	38.50	101.80	200.75	513.42
	50	1.42	2.48	3.89	7.92	21.40	43.04	113.82	224.44	574.02
	60	1.56	2.71	4.26	8.67	23.44	47.15	124.68	245.87	628.81
	75	1.74	3.03	4.77	9.70	26.21	52.71	139.39	274.89	703.03
	100	2.01	3.50	5.50	11.20	30.27	60.87	160.96	317.41	811.79
	130	2.29	3.99	6.28	12.77	34.51	69.40	183.52	361.91	925.58
Through 100 feet of service pipe, no back pressure.	30	0.66	1.16	1.84	3.78	10.40	21.30	58.19	118.13	317.23
	40	0.77	1.34	2.12	4.36	12.01	24.59	67.19	136.41	366.30
	50	0.86	1.50	2.37	4.88	13.43	27.50	75.13	152.51	409.54
	60	0.94	1.65	2.60	5.34	14.71	30.12	82.30	167.06	448.63
	75	1.05	1.84	2.91	5.97	16.45	33.68	92.01	186.78	501.58
	100	1.22	2.13	3.36	6.90	18.99	38.89	106.24	215.68	579.18
	130	1.39	2.42	3.83	7.86	21.66	44.34	121.14	245.91	660.36
Through 100 feet of service pipe and 15 feet vertical rise.	30	0.55	0.96	1.52	3.11	8.57	17.55	47.90	97.17	260.56
	40	0.66	1.15	1.81	3.72	10.24	20.95	57.20	116.01	311.09
	50	0.75	1.31	2.06	4.24	11.67	23.87	65.18	132.20	354.49
	60	0.83	1.45	2.29	4.70	12.94	26.48	72.28	146.61	393.13
	75	0.94	1.64	2.59	5.32	14.64	29.96	81.79	165.90	444.85
	100	1.10	1.92	3.02	6.21	17.10	35.00	95.55	193.82	519.72
	130	1.26	2.20	3.48	7.14	19.66	40.23	109.82	222.75	597.31
Through 100 feet of service pipe and 30 feet vertical rise.	30	0.44	0.77	1.22	2.50	6.80	14.11	38.63	78.54	211.54
	40	0.55	0.97	1.53	3.15	8.68	17.79	48.68	98.98	266.59
	50	0.65	1.14	1.79	3.69	10.16	20.82	56.98	115.87	312.08
	60	0.73	1.28	2.02	4.15	11.45	23.47	64.22	130.59	351.73
	75	0.84	1.47	2.32	4.77	13.15	26.95	73.76	149.99	403.98
	100	1.00	1.74	2.75	5.65	15.58	31.93	87.38	177.67	478.55
	130	1.15	2.02	3.19	6.55	18.07	37.02	101.33	206.04	554.96

Loss of Head in Pipe by Friction

(Pelton Water Wheel Company.)

The following table shows the loss of head by friction in each 100 feet in length of different diameters of pipe, when discharging the tabulated quantities of water per minute:

v = velocity in feet per second;
H = loss of head by friction in feet;
Q = discharge in cubic feet per minute.

v	Inside diameter of pipe in inches											
	6		7		8		9		10		11	
	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q
2.0	.39	23.5	.33	32.0	.30	41.9	.26	53.0	.23	65.4	.21	79.
2.2	.46	25.9	.40	35.3	.35	46.1	.31	58.3	.28	72.	.25	87.
2.4	.54	28.2	.46	38.5	.41	50.2	.36	63.6	.32	78.5	.29	95.
2.6	.63	30.6	.54	41.7	.47	54.4	.42	68.9	.37	85.1	.34	103.
2.8	.72	32.9	.61	44.9	.54	58.6	.48	74.2	.43	91.6	.39	111.
3.0	.81	35.3	.69	48.1	.61	62.8	.54	79.5	.48	98.2	.44	119.
3.2	.91	37.7	.78	51.3	.68	67.0	.60	84.8	.54	105.	.49	127.
3.4	1.02	40.0	.87	54.5	.76	71.2	.68	90.1	.61	111.	.55	134.
3.6	1.13	42.4	.96	57.7	.84	75.4	.75	95.4	.67	118.	.61	142.
3.8	1.25	44.7	1.07	60.9	.93	79.6	.83	101.	.74	124.	.68	150.
4.0	1.37	47.1	1.17	64.1	1.02	83.7	.91	106.	.82	131.	.74	158.
4.2	1.49	49.5	1.28	67.3	1.12	87.9	.99	111.	.89	137.	.81	166.
4.4	1.62	51.8	1.39	70.5	1.22	92.1	1.08	116.	.97	144.	.88	174.
4.6	1.76	54.1	1.51	73.7	1.32	96.3	1.17	122.	1.05	150.	.96	182.
4.8	1.90	56.5	1.63	76.9	1.43	100.0	1.27	127.	1.14	157.	1.04	190.
5.0	2.05	58.9	1.76	80.2	1.54	105.	1.37	132.	1.23	163.	1.12	198.
5.2	2.21	61.2	1.89	83.3	1.65	109.	1.47	138.	1.32	170.	1.20	206.
5.4	2.37	63.6	2.03	86.6	1.77	113.	1.57	143.	1.41	177.	1.28	214.
5.6	2.53	65.9	2.17	89.8	1.89	117.	1.68	148.	1.51	183.	1.37	222.
5.8	2.70	68.3	2.31	93.0	2.01	121.	1.80	154.	1.61	190.	1.46	229.
6.0	2.87	70.7	2.46	96.2	2.15	125.	1.92	159.	1.71	196.	1.56	237.
7.0	3.81	82.4	3.26	112.0	2.85	146.	2.52	185.	2.28	229.	2.07	277.

v	12		13		14		15		16		18	
	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q
2.0	.198	94.	.183	110.	.169	128.	.158	147.	.147	167.	.132	212.
2.2	.234	103.	.216	121.	.200	141.	.187	162.	.175	184.	.156	233.
2.4	.273	113.	.252	133.	.234	154.	.218	176.	.205	201.	.182	254.
2 6	.315	122.	.290	144.	.270	167.	.252	191.	.236	218.	.210	275.
2.8	.360	132.	.332	156.	.308	179.	.288	206.	.270	234.	.240	297.
3.0	.407	141.	.375	166.	.349	192.	.325	221.	.306	251.	.271	318.
3.2	.457	151.	.422	177.	.392	205.	.366	235.	.343	268.	.305	339.
3.4	.510	160.	.471	188.	.438	218.	.408	250.	.383	284.	.339	360.

Loss of Head in Pipe by Friction (Continued)

v	12 *H*	12 *Q*	13 *H*	13 *Q*	14 *H*	14 *Q*	15 *H*	15 *Q*	16 *H*	16 *Q*	18 *H*	18 *Q*
3.6	.566	169.	.522	199.	.485	231.	.452	265.	.425	301.	.377	382.
3.8	.624	179.	.576	210.	.535	243.	.499	280.	.468	318.	.416	403.
4.0	.685	188.	.632	221.	.587	256.	.548	294.	.513	335.	.456	424.
4.2	.749	198.	.691	232.	.641	269.	.598	309.	.561	352.	.499	445.
4.4	.815	207.	.751	243.	.698	282.	.651	324.	.611	368.	.542	466.
4.6	.883	217.	.815	254.	.757	295.	.707	339.	.662	385.	.588	488.
4.8	.954	226.	.881	265.	.818	308.	.763	353.	.715	402.	.636	509.
5.0	1.028	235.	.949	276.	.881	321.	.822	368.	.770	419.	.685	530.
5.2	1.104	245.	1.020	287.	.947	333.	.883	383.	.828	435.	.736	551.
5.4	1.183	254.	1.092	298.	1.014	346.	.947	397.	.888	452.	.788	572.
5.6	1.26	264.	1.167	309.	1.083	359.	1.011	412.	.949	469.	.843	594.
5.8	1.34	273.	1.245	321.	1.155	372.	1.078	427.	1.011	486.	.899	615.
6.0	1.43	283.	1.325	332.	1.229	385.	1.148	442.	1.076	502.	.957	636.
7.0	1.91	330.	1.75	387.	1.630	449.	1.520	515.	1.430	586.	1.270	742.

Inside diameter of pipe in inches

v	20 *H*	20 *Q*	22 *H*	22 *Q*	24 *H*	24 *Q*	26 *H*	26 *Q*	28 *H*	28 *Q*	30 *H*	30 *Q*
2.0	.119	262.	.108	316.	.098	377.	.091	442.	.084	513.	.079	589.
2.2	.140	288.	.127	348.	.116	414.	.108	486.	.099	564.	.093	648.
2.4	.164	314.	.149	380.	.136	452.	.126	531.	.116	616.	.109	707.
2.6	.189	340.	.171	412.	.157	490.	.145	575.	.134	667.	.126	766.
2.8	.216	366.	.195	443.	.180	528.	.165	619.	.153	718.	.144	824.
3.0	.245	393.	.222	475.	.204	565.	.188	663.	.174	770.	.163	883.
3.2	.275	419.	.249	507.	.229	603.	.211	708.	.195	821.	.182	942.
3.4	.306	445.	.278	538.	.255	641.	.235	752.	.218	872.	.204	1001.
3.6	.339	471.	.308	570.	.283	678.	.261	796.	.242	923.	.226	1060.
3.8	.374	497.	.340	601.	.312	716.	.288	840.	.267	973.	.249	1119.
4.0	.410	523.	.373	633.	.342	754.	.315	885.	.293	1026.	.273	1178.
4.2	.449	550.	.408	665.	.374	791.	.345	929.	.320	1077.	.299	1237.
4.4	.488	576.	.444	697.	.407	829.	.375	973.	.348	1129.	.325	1296.
4.6	.529	602.	.482	728.	.441	867.	.407	1017.	.378	1180.	.353	1355.
4.8	.572	628.	.521	760.	.476	905.	.440	1062.	.409	1231.	.381	1414.
5.0	.617	654.	.561	792.	513	942.	.474	1106.	.440	1283.	.411	1472.
5.2	.662	680.	.602	823.	.552	980.	.510	1150.	.473	1334.	.441	1531.
5.4	.710	707.	645	855.	.591	1018.	.546	1194.	.507	1385.	.473	1590.
5.6	.758	733.	.690	887.	.632	1055.	.583	1239.	.542	1437.	.506	1649.
5.8	.809	759.	.735	918.	.674	1093.	.622	1283.	.578	1488.	540	1708.
6.0	.861	785.	.782	950.	.717	1131.	.662	1327.	.615	1539.	.574	1767.
7.0	1.143	916.	1.040	1109.	.953	1319.	.879	1548.	.817	1796.	.762	2061.

Loss of Head in Pipe by Friction (Concluded)

v	33		36		39		42		45		48	
	H	*Q*	*H*	*Q*	*H*	*Q*	*H*	*Q*	*H*	*Q*	*H*	*Q*
2.0	.073	712.	.066	848.	.061	995.	.057	1155.	.053	1325.	.050	1508.
2.2	.085	785.	.078	933.	.072	1094.	.067	1270.	.063	1456.	.059	1658.
2.4	.100	855.	.091	1018.	.084	1194.	.079	1385.	.073	1590.	.069	1809.
2.6	.115	927.	.104	1100.	.097	1294.	.090	1500.	.084	1721.	.079	1960.
2.8	.131	1000.	.119	1188.	.111	1394.	.103	1617.	.096	1855.	.090	2110.
3.0	.148	1070.	.135	1273.	.125	1492.	.117	1730.	.109	1987.	.102	2260.
3.2	.167	1140.	.152	1367.	.141	1591.	.131	1845.	.122	2120.	.115	2410.
3.4	.186	1210.	.169	1442.	.157	1690.	.146	1961.	.136	2250.	.128	2560.
3.6	.206	1282.	.188	1527.	.174	1790.	.162	2079.	.151	2382.	.142	2715.
3.8	.226	1355.	.207	1612.	.191	1891.	.178	2190.	.166	2515.	.156	2865.
4.0	.248	1425.	.228	1697.	.210	1990.	.195	2310.	.182	2650.	.171	3016.
4.2	.270	1495.	.249	1782.	.229	2091.	.213	2422.	.198	2780.	.186	3165.
4.4	.295	1568.	.271	1866.	.250	2190.	.232	2540.	.216	2910.	.203	3318.
4.6	.321	1640.	.294	1951.	.271	2290.	.252	2658.	.235	3045.	.220	3470.
4.8	.346	1710.	.318	2036.	.293	2389.	.270	2770.	.254	3180.	.238	3619.
5.0	.374	1780.	.342	2121.	.316	2490.	.294	2885.	.273	3310.	.256	3770.
5.2	.403	1852.	.368	2206.	.342	2590.	.317	3000.	.296	3442.	.278	3920.
5.4	.430	1922.	.394	2291.	.364	2689.	.338	3115.	.315	3578.	.295	4071.
5.6	.453	1995.	.421	2376.	.393	2790.	.374	3230.	.340	3710.	.319	4222.
5.8	.495	2065.	.450	2460.	.419	2886.	.389	3348.	.363	3840.	.340	4373.
6.0	.520	2140.	.479	2545.	.441	2986.	.408	3461.	.382	3970.	.358	4524.
7.0	.693	2495.	.636	2968.	.586	3484.	.545	4030.	.509	4638.	.476	5277.

(Column headings 33–48: Inside diameter of pipe in inches)

The above table is based on Cox's reconstruction of Weisbach's formula, using the denominator 1000 instead of 1200, to be on the safe side, allowing 20% for the loss of head due to the laps and rivet-heads in the pipe. Cox's formula, using the denominator 1200, is given below.

Example. Given 200 feet head and 600 feet of 11-inch pipe, carrying 119 cubic feet of water per minute. To find the effective head: In right-hand column, under 11-inch pipe, find 119 cubic feet; opposite this will be found the loss by friction in 100 feet of length for this amount of water, which is 0.44. Multiply this by the number of hundred feet of pipe, which is 6, and we have 2.64 feet, which is the loss of head. Therefore the effective head is 200 − 2.64 = 197.36.

Explanation. The loss of head by friction in a pipe depends not only upon diameter and length, but upon the quantity of water passed through it. The head or pressure is what would be indicated by a pressure-gage attached to the pipe near the outlet. Readings of gage should be taken while the water is flowing from the nozzle.

To reduce heads in feet to pressure in pounds multiply by 0.433. To reduce pounds pressure to feet multiply by 2.309.

Cox's Formula. (Kent's Mechanical Engineers' Pocket Book.) Weisbach's formula for loss of head caused by the friction of water in pipes is as follows:

$$\text{Friction-head} = \left(0.0144 + \frac{0.01716}{\sqrt{v}}\right)\frac{l \cdot v^2}{5.367\, d},$$

where l = length of pipe in feet;
v = velocity of the water in feet per second;
d = diameter of pipe in inches.

William Cox (Amer. Mach., Dec. 28, 1893) gives a simpler formula which gives almost identical results:

$$H = \text{friction-head in feet} = \frac{l}{d}\,\frac{(4v^2 + 5v - 2)}{1200}, \quad (1)$$

$$\frac{Hd}{l} = \frac{4v^2 + 5v - 2}{1200}, \quad (2)$$

He gives a table by means of which the value of $\frac{4v^2 + 5v - 2}{1200}$ is at once obtained when v is known, and vice versa.

Values of $\frac{4v^2 + 5v - 2}{1200}$

v	0.0	0.1	0.2	0.3	0.4
1	.00583	.00695	.00813	.00938	.01070
2	.02000	.02178	.02363	.02555	.02753
3	.04083	.04328	.04580	.04838	.05103
4	.06833	.07145	.07463	.07788	.08120
5	.10250	.10628	.11013	.11405	.11803
6	.14333	.14778	.15230	.15688	.16153
7	.19083	.19595	.20113	.20638	.21170
8	.24500	.25078	.25663	.26255	.26853
9	.30583	.31228	.31880	.32538	.33203
10	.37333	.38045	.38763	.39488	.40220
11	.44750	.45528	.46313	.47105	.47903
12	.52833	.53678	.54530	.55388	.56253
13	.61583	.62495	.63413	.64338	.65270
14	.71000	.71978	.72963	.73955	.74953
15	.81083	.82128	.83180	.84238	.85303
16	.91833	.92945	.94063	.95188	.96320
17	1.03250	1.04428	1.05613	1.06805	1.08003
18	1.15333	1.16578	1.17830	1.19088	1.20353
19	1.28083	1.29395	1.30713	1.32038	1.33370
20	1.41500	1.42878	1.44263	1.45655	1.47053
21	1.55583	1.57028	1.58480	1.59938	1.61403

v	0.5	0.6	0.7	0.8	0.9
1	.01208	.01353	.01505	.01663	.01828
2	.02958	.03170	.03388	.03613	.03845
3	.05375	.05653	.05938	.06230	.06528
4	.08458	.08803	.09155	.09513	.09878
5	.12208	.12620	.13038	.13463	.13895
6	.16625	.17103	.17588	.18080	.18578
7	.21708	.22253	.22805	.22363	.23928
8	.27458	.28070	.28688	.29313	.29945
9	.33875	.34553	.35238	.35930	.36628
10	.40958	.41703	.42455	.43213	.43978
11	.48708	.49520	.50338	.51163	.51995
12	.57125	.58003	.58888	.59780	.60678
13	.66208	.67153	.68105	.69063	.70028
14	.75958	.76970	.77988	.79013	.80045
15	.86375	.87453	.88538	.89630	.90728
16	.97458	.98603	.99755	1.00913	1.02078
17	1.09208	1.10420	1.11638	1.12863	1.14095
18	1.21625	1.22903	1.24188	1.25480	1.26778
19	1.34708	1.36053	1.37405	1.38763	1.40128
20	1.48458	1.49870	1.51288	1.52713	1.54145
21	1.62875	1.64353	1.65838	1.67330	1 68828

The use of the formula and table is illustrated as follows:

Given a pipe 5 inches diameter and 1000 feet long, with 49 feet head, what will the discharge be?

If the velocity v is known in feet per second, the discharge is 0.32725 d^2v cubic foot per minute.

By equation (2) we have $\dfrac{4v^2+5v-2}{1200}=\dfrac{Hd}{l}=\dfrac{49\times 5}{1000}=0.245;$

whence, by table, v = real velocity = 8 feet per second.

The discharge in cubic feet per minute, if v is velocity in feet per second and d diameter in inches, is 0.32725 d^2v, whence, discharge = $0.32725\times 25\times 8=65.45$ cubic feet per minute.

The velocity due to the head, if there were no friction, is $8.025\sqrt{H}=56.175$ feet per second, and the discharge at that velocity would be $0.32725\times 25\times 56.175=460$ cubic feet per minute.

Suppose it is required to deliver this amount, 460 cubic feet, at a velocity of 2 feet per second; what diameter of pipe of the same length and under the same head will be required and what will be the loss of head by friction?

$$d=\text{diameter}=\sqrt{\frac{Q}{v\times 0.32725}}=\sqrt{\frac{460}{2\times 0.32725}}=\sqrt{703}=26.5\text{ inches.}$$

Having now the diameter, the velocity, and the discharge, the friction-head is calculated by equation (1) and use of the table; thus,

$$H=\frac{l}{d}\,\frac{(4v^2+5v-2)}{1200}=\frac{1000}{26.5}\times 0.02=\frac{20}{26.5}=0.75\text{ foot,}$$

thus leaving $49-0.75$ = say 48 feet effective head applicable to power-producing purposes.

MEASUREMENT OF FLOWING WATER

(From Kent's Mechanical Engineers' Pocket Book.)

Piezometer. If a vertical or oblique tube be inserted into a pipe containing water under pressure, the water will rise in the former, and the vertical height to which it rises will be the head producing the pressure at the point where the tube is attached. Such a tube is called a piezometer or pressure measure. If the water in the piezometer falls below its proper level it shows that the pressure in the main pipe has been reduced by an obstruction between the piezometer and the reservoir. If the water rises above its proper level it indicates that the pressure there has been increased by an obstruction beyond the piezometer.

If we imagine a pipe full of water to be provided with a number of piezometers, then a line joining the tops of the columns of water in them is the hydraulic grade-line.

Pitot Tube. The Pitot tube is used for measuring the velocity of fluids in motion. It has been used with great success in measuring the flow of natural gas. (S. W. Robinson, Report Ohio Geol. Survey, 1890.) (See also Van Nostrand's Mag., Vol. XXXV.) It is simply a tube so bent that a short leg extends into the current of fluid flowing from a tube, with the plane of the entering orifice opposed at right angles to the direction of the current. The pressure caused by the impact of the current is transmitted through the tube to a pressure-gage of any kind, such as a column of water or of mercury, or a Bourdon spring-gage. From the pressure thus indicated and the known density and temperature of the flowing fluid is obtained the head corresponding to the pressure, and from this the velocity. In a modification of the Pitot tube described by Professor Robinson, there are two tubes inserted into the pipe conveying the gas, one of which has the plane of the orifice at right angles to the current, to receive the static pressure plus the pressure due to impact; the other has the plane of its orifice parallel to the current so as to receive the static pressure only. These tubes are connected to the legs of a U tube partly filled with mercury, which then registers the difference in pressure in the two tubes, from which the velocity may be calculated. Comparative tests of Pitot tubes with gas-meters, for measurement of the flow of natural gas, have shown an agreement within 3%.

It appears from experiments made by W. M. White, described in a paper before the Louisiana Eng'g Socy., 1901, by Williams, Hubbell and Fenkel (Trans. A. S. C. E., 1901), and by W. B. Gregory (Trans. A. S. M. E., 1903), that in the formula for the Pitot tube, $V = c\sqrt{2gH}$, in which V is the velocity of the current in feet per second, H the head in feet of the fluid corresponding to the pressure measured by the tube, and c an experimental coefficient, $c = 1$ when the plane at the point of the tube is exactly at right angles with the direction of the current, and when the static pressure is correctly measured. The total pressure produced by a jet striking an extended plane surface at right angles to

it, and escaping parallel to the plate, equals twice the product of the area of the jet into the pressure calculated from the "head due to the velocity," and for this case $H = 2 \times \frac{V^2}{2g}$, instead of $\frac{V^2}{2g}$; but as found in White's experiments the maximum pressure at the point on the plate exactly opposite the jet corresponds to $h = \frac{V^2}{2g}$. Experiments made with four different shapes of nozzles placed under the center of a falling stream of water showed that the pressure produced was capable of sustaining a column of water almost exactly equal to the height of the falling water.

Tests by J. A. Knesche (Indust. Eng'g, Nov., 1909), in which a Pitot tube was inserted in a 4-inch water pipe, gave $C =$ about 0.77 for velocities of 2.5 to 8 feet per second, and smaller values for lower velocities. He holds that the coefficient of a tube should be determined by experiment before its readings can be considered accurate.

Maximum and Mean Velocities in Pipes. Williams, Hubbell and Fenkel (Trans. A. S. C. E., 1901) found a ratio of 0.84 between the mean and the maximum velocities of water flowing in closed circular conduits, under normal conditions, at ordinary velocities; whereby observations of velocity taken at the center under such conditions, with a properly rated Pitot tube, may be relied on to give results within 3% of correctness.

The Venturi Meter, invented by Clemens Herschel, and described in a pamphlet issued by the Builders' Iron Foundry of Providence, R. I., is named for Venturi, who first called attention, in 1796, to the relation between the velocities and pressures of fluids when flowing through converging and diverging tubes. It consists of two parts, — the tube, through which the water flows, and the recorder, which registers the quantity of water that passes through the tube. The tube takes the shape of two truncated cones joined in their smallest diameters by a short throat-piece. At the up-stream end and at the throat there are pressure-chambers, at which points the pressures are taken.

The action of the tube is based on that property which causes the small section of a gently expanding frustum of a cone to receive, without material resultant loss of head, as much water at the smallest diameter as is discharged at the large end, and on that further property which causes the pressure of the water flowing through the throat to be less, by virtue of its greater velocity, than the pressure at the up-stream end of the tube, each pressure being at the same time a function of the velocity at that point and of the hydrostatic pressure which would obtain were the water motionless within the pipe.

The recorder is connected with the tube by pressure-pipes which lead to it from the chambers surrounding the up-stream end and the throat of the tube. It may be placed in any convenient position within 1000 feet of the meter. It is operated by a weight and clockwork. The difference of pressure or head at the entrance and at the throat of the

meter is balanced in the recorder by the difference of level in two columns of mercury in cylindrical receivers, one within the other. The inner carries a float, the position of which is indicative of the quantity of water flowing through the tube. By its rise and fall the float varies the time of contact between an integrating drum and the counters by which the successive readings are registered.

There is no limit to the sizes of the meters nor the quantity of water that may be measured. Meters with 24-inch, 36-inch, 48-inch, and even 20-foot tubes can be readily made.

Measurement by Venturi Tubes (Trans. A. S. C. E., Nov., 1887, and Jan., 1888). Mr. Herschel recommends the use of a Venturi tube, inserted in the force main of the pumping engine, for determining the quantity of water discharged. Such a tube applied to a 24-inch main has a total length of about 20 feet. At a distance of 4 feet from the end nearest the engine the inside diameter of the tube is contracted to a throat having a diameter of about 8 inches. A pressure gage is attached to each of two chambers, the one surrounding and communicating with the entrance or main pipe, the other with the throat. According to experiments made upon two tubes of this kind, one 4 inches in diameter at the throat and 12 inches at the entrance, and the other about 36 inches in diameter at the throat and 9 feet at its entrance, the quantity of water which passes through the tube is very nearly the theoretical discharge through an opening having an area equal to that of the throat, and a velocity which is that due to the difference in head shown by the two gages. Mr. Herschel states that the coefficient for these two widely varying sizes of tubes, and for a wide range of velocity through the pipe, was found to be within 2%, either way, of 98%. In other words, the quantity of water flowing through the tube per second is expressed within two per cent by the formula $W = 0.98\,A\,\sqrt{2\,gh}$, in which A is the area of the throat of the tube, h the head, in feet, corresponding to the difference in the pressure of the water entering the tube and that found at the throat, and $g = 32.16$.

Measurement of Discharge of Pumping Engines by Means of Nozzles (Trans. A. S. M. E., Vol. XII, 575). The measurement of water by computation from its discharge through orifices, or through the nozzles of fire hose, furnishes a means of determining the quantity of water delivered by a pumping engine, which can be applied without much difficulty. John R. Freeman (Trans. A. S. C. E., Nov., 1889) describes a series of experiments covering a wide range of pressures and sizes, and the results show that the coefficient of discharge for a smooth nozzle of ordinary good form was within one-half of 1%, either way, of .977; the diameter of the nozzle being accurately calipered, and the pressures being determined by means of an accurate gage attached to a suitable piezometer at the base of the play-pipe.

In order to use this method for determining the quantity of water discharged by a pumping engine, it would be necessary to provide a pressure-box to which the water would be conducted, and attach to the

box as many nozzles as would be required to carry off the water. According to Mr. Freeman's estimate, four 1¼-inch nozzles, thus connected, with a pressure of 80 pounds per square inch, would discharge the full capacity of a 2½-million engine. He also suggests the use of a portable apparatus with a single opening for discharge, consisting essentially of a Siamese nozzle, so-called, the water being carried to it by three or more lines of fire hose.

To insure reliability for these measurements, it is necessary that the shut-off valve in the force-main, or the several shut-off valves, should be tight, so that all the water discharged by the engine may pass through the nozzles.

THE MINER'S INCH

(From Merriman's Treatise on Hydraulics.)

The miner's inch may be roughly defined to be the quantity of water which will flow from a vertical standard orifice one inch square, when the head on the center of the orifice is 6½ inches. The coefficient of discharge is about 0.623, and accordingly the actual discharge from the orifice in cubic feet per second is

$$q = \frac{1}{144} \times 0.623 \times 8.02 \sqrt{\frac{6.5}{12}} = 0.0255,$$

and the discharge in one minute is $60 \times 0.0255 = 1.53$ cubic feet. The mean value of one miner's inch is therefore about 1.5 cubic feet per minute.

The actual value of the miner's inch, however, differs considerably in different localities. Bowie states that in different counties of California it ranges from 1.20 to 1.76 cubic feet per minute The reason for these variations is due to the fact that when water is bought for mining or irrigating purposes, a much larger quantity than one miner's inch is required, and hence larger orifices than one square inch are needed. Thus at Smartsville, a vertical orifice or module, 4 inches deep and 250 inches long, with a head of 7 inches above the top edge, is said to furnish 1000 miner's inches. Again at Columbia Hill, a module 12 inches deep and 12¾ inches wide, with a head of 6 inches above the upper edge, is said to furnish 200 miner's inches. In Montana the customary method of measurement is through a vertical rectangle, one inch deep, with a head on the center of the orifice of 4 inches, and the number of miner's inches is said to be the same as the number of linear inches in the rectangle; thus under the given head an orifice one inch deep and 60 inches long would furnish 60 miner's inches. The discharge of this is said to be about 1.25 cubic feet per minute, or 75 cubic feet per hour.

The following are the values of the miner's inch in different parts of the Unites States. In California and Montana it is established by law that 40 miner's inches shall be the equivalent of one cubic foot per second, and in Colorado 38.4 miner's inches is the equivalent. In

other States and Territories there is no legal value, but by common agreement 50 miner's inches is the equivalent of one cubic foot per second in Arizona, Idaho, Nevada, and Utah; this makes the miner's inch equal to 1.2 cubic feet per minute.

A module is an orifice which is used in selling water, and which under a constant head is to furnish a given number of miner's inches, or a given quantity per second. The size and proportions of modules vary greatly in different localities, but in all cases the important feature to be observed is that the head should be maintained nearly constant in order that the consumer may receive the amount of water for which he bargains and no more.

The simplest method of maintaining a constant head is by placing the module in a chamber which is provided with a gate that regulates the entrance of water from the main reservoir or canal. This gate is raised or lowered by an inspector once or twice a day so as to keep the surface of the water in the chamber at a given mark. This plan is a costly one, on account of the wages of the inspector, except in works where many modules are used and where a daily inspection is necessary in any event, and it is not well adapted to cases where there are frequent and considerable fluctuations in the surface of the water in the feeding canal.

Numerous methods have been devised to secure a constant head by automatic appliances; for instance, the gate which admits water into the chamber may be made to rise and fall by means of a float upon the surface; the module itself may be made to decrease in size when the water rises, and to increase when it falls, by a gate or by a tapering plug which moves in and out and whose motion is controlled by a float. These self-acting contrivances, however, are liable to get out of order, and require to be inspected more or less frequently. Another method is to have the water flow over the crest of a weir as soon as it reaches a certain height.

The use of the miner's inch, or of a module, as a standard for selling water, is awkward and confusing, and for the sake of uniformity it is greatly to be desired that water should always be bought and sold by the cubic foot per second. Only in this way can comparison readily be made, and the consumer be sure of obtaining exact value for his money.

The cut, Fig. 129, shows the form of measuring-box ordinarily used, and the following table gives the discharge in cubic feet per minute of a miner's inch of water, as measured under the various heads and different lengths and heights of apertures used in California.

Fig. 129. Miner's Inch Measuring Box

Miner's Inch Measurements

(Pelton Water Wheel Company.)

Length of opening in inches	Opening 2 inches high			Opening 4 inches high		
	Head to center, 5 inches	Head to center, 6 inches	Head to center, 7 inches	Head to center, 5 inches	Head to center, 6 inches	Head to center, 7 inches
	Cubic feet	Cubic feet	Cubic feet	Cubic feet	Cubic feet	Cubic feet
4	1.348	1 473	1 589	1.320	1.450	1 570
6	1 355	1.480	1 596	1 336	1.470	1.[illegible]
8	1.359	1 484	1 600	1.344	1.481	1 [illegible]
10	1 361	1.485	1 602	1 349	1.487	1 615
12	1.363	1 487	1 604	1 352	1.491	1 620
14	1 364	1.488	1 604	1.354	1 494	1 623
[illegible]	1 365	1 489	1 605	1 356	1.496	1 626
18	1 365	1.489	1.606	1.357	1 498	1 628
20	1 365	1 490	1 606	1 359	1 499	1 630
22	1 366	1.490	1 607	1 359	1.500	1 631
24	1.366	1.490	1 607	1 360	1.501	1 632
26	1 366	1.490	1 607	1 361	1.502	1.633
28	1 367	1 491	1.607	1 361	1 503	1.634
30	1 367	1.491	1.608	1.362	1 503	1 635
40	1.367	1 492	1 608	1 363	1 505	1 637
50	1 368	1 493	1.609	1 364	1 507	1.639
60	1 368	1.493	1 609	1.365	1 508	1.640
70	1.368	1 493	1.609	1.365	1.508	1 641
80	1 368	1.493	1 609	1.366	1.509	1 641
90	1 369	1 493	1 610	1.366	1.509	1.641
100	1 369	1 494	1 610	1.366	1.509	1.642

WATER POWER

(From Kent's Mechanical Engineers' Pocket Book.)

Power of a Fall of Water — Efficiency. The gross power of a fall of water is the product of the weight of water discharged in a unit of time into the total head, i.e., the difference of vertical elevation of the upper surface of the water at the points where the fall in question begins and ends. The term "head" used in connection with water-wheels is the difference in height from the surface of the water in the wheel-pit to the surface in the penstock when the wheel is running.

If $Q =$ cubic feet of water discharged per second, $D =$ weight of a cubic foot of water $= 62.36$ pounds at 60° F., $H =$ total head in feet; then

$$DQH = \text{gross power in foot-pounds per second,}$$

and

$$DQH \div 550 = 0.1134\ QH = \text{gross horse-power.}$$

If Q' is taken in cubic feet per minute,

$$\text{H.P.} = \frac{Q'H \times 62.36}{33\,000} = .00189\ Q'H.$$

A water-wheel or motor of any kind cannot utilize the whole of the head H, since there are losses of head at both the entrance to and the exit from the wheel. There are also losses of energy due to friction of the water in its passage through the wheel. The ratio of the power developed by the wheel to the gross power of the fall is the efficiency of the wheel. For 75% efficiency, net horse-power $= 0.00142\ Q'H = \dfrac{Q'H}{706}$.

A head of water can be made use of in one or other of the following ways, viz.:

First. By its weight, as in the water-balance and in the overshot wheel.

Second. By its pressure, as in turbines and in the hydraulic engine, hydraulic press, crane, etc.

Third. By its impulse, as in the undershot wheel, and in the Pelton wheel.

Fourth. By a combination of the above.

Horse-power of a Running Stream. The gross horse-power is H.P. $= QH \times 62.36 \div 550 = 0.1134\ QH$, in which Q is the discharge in cubic feet per second actually impinging on the float or bucket, and $H =$ theoretical head due to the velocity of the stream $= \dfrac{v^2}{2g} = \dfrac{v^2}{64.4}$, in which v is the velocity in feet per second. If Q' be taken in cubic feet per minute H.P. $= 0.00189\ Q'H$.

Thus, if the floats of an undershot wheel driven by a current alone be 5 feet × 1 foot, and the velocity of stream = 210 feet per minute,

or $3\frac{1}{2}$ feet per second, of which the theoretical head is 0.19 feet, $Q =$ 5 square feet $\times$ 210 = 1050 cubic feet per minute; H.P. = 1050 $\times$ 0.19 $\times$ 0.00189 = 0.377 H.P.

The wheels would realize only about 0.4 of this power, on account of friction and slip, or 0.151 H.P., or about 0.03 H.P. per square foot of float, which is equivalent to 33 square feet of float per H.P.

Current Motors. A current motor could only utilize the whole power of a running stream if it could take all the velocity out of the water, so that it would leave the floats or buckets with no velocity at all; or in other words, it would require the backing up of the whole volume of the stream until the actual head was equivalent to the theoretical head due to the velocity of the stream. As but a small fraction of the velocity of the stream can be taken up by a current motor, its efficiency is very small. Current motors may be used to obtain small amounts of power from large streams, but for large powers they are not practicable.

Bernoulli's Theorem. Energy of Water Flowing in a Tube. The head due to the velocity is $\frac{v^2}{2g}$; the head due to the pressure is $\frac{f}{w}$; the head due to actual height above the datum plane is h feet. The total head is the sum of these $= \frac{v^2}{2g} + h + \frac{f}{w}$, in feet, in which $v =$ velocity in feet per second, $f =$ pressure in pounds per square foot, $w =$ weight of 1 cubic foot of water = 62.36 pounds. If $p =$ pressure in pounds per square inch $\frac{f}{w} = 2.309\,p$. If a constant quantity of water is flowing through a tube in a given time, the velocity varying at different points on account of changes in the diameter, the energy remains constant (loss by friction excepted) and the sum of the three heads is constant, the pressure head increasing as the velocity decreases, and vice versa. This principle is known as "Bernoulli's Theorem."

In hydraulic transmission the velocity and the height above datum are usually small compared with the pressure-head. The work or energy of a given quantity of water under pressure = its volume in cubic feet $\times$ its pressure in pounds per square foot; or if $Q =$ quantity in cubic feet per second, and $p =$ pressure in pounds per square inch, $W =$ $144\,pQ$ and the H.P. $= \frac{144\,pQ}{550} = 0.2618\,pQ$.

Table for Calculating the Horse-power of Water Heads

(Pelton Water Wheel Company.)

The following table gives the horse-power of 1 cubic foot of water per minute under heads from 1 up to 2100 feet.

Heads in feet	Horse-power	Heads in feet	Horse-power	Heads in feet	Horse-power	Heads in feet	Horse-power
1	.0016098	220	.354156	430	.692214	1050	1.690290
20	.032196	230	.370254	440	.708312	1100	1.770780
30	.048294	240	.386352	450	.724410	1150	1.851270
40	.064392	250	.402450	460	.740508	1200	1.931760
50	.080490	260	.418548	470	.756606	1250	2.012250
60	.096588	270	.434646	480	.772704	1300	2.092740
70	.112686	280	.450744	490	.788802	1350	2.173230
80	.128784	290	.466842	500	.804900	1400	2.253720
90	.144882	300	.482940	520	.837096	1450	2.334210
100	.160980	310	.499038	540	.869292	1500	2.414700
110	.177078	320	.515136	560	.901488	1550	2.495190
120	.193176	330	.531234	580	.933684	1600	2.575680
130	.209274	340	.547332	600	.965880	1650	2.656170
140	.225372	350	.563430	650	1.046370	1700	2.736660
150	.241470	360	.579528	700	1.126860	1750	2.817150
160	.257568	370	.595626	750	1.207350	1800	2.897640
170	.273666	380	.611724	800	1.287840	1850	2.978130
180	.289764	390	.627822	850	1.368330	1900	3.058620
190	.305862	400	.643920	900	1.448820	1950	3.139110
200	.321960	410	.660018	950	1.529310	2000	3.219600
210	.338058	420	.676116	1000	1.609800	2100	3.380580

When the Exact Head is Found in Above Table

Example: Have 100-foot head and 50 cubic feet of water per minute. How many horse-power?

By reference to the above table the horse-power of each cubic foot under 100-foot head will be found to be .16098. This amount multiplied by the number of cubic feet per minute, 50, will give 8.05 horse-power.

When Exact Head is Not Found in Table

Take the horse-power of 1 cubic foot per minute under 1-foot head, and multiply by the number of cubic feet available, and then by the number of feet head. The product will be the required horse-power.

Note: The above table is based upon an efficiency of 85 per cent.

Gallons and Cubic Feet

United States Gallons in a Given Number of Cubic Feet

(1 cubic foot = 7.480519 U. S. gallons; 1 gallon = 231 cubic inches = 0.13368056 cubic foot.)

Cubic feet	Gallons	Cubic feet	Gallons	Cubic feet	Gallons
0.1	0.75	50	374.0	8 000	59 844.2
0.2	1.50	60	448.8	9 000	67 324.7
0.3	2.24	70	523.6	10 000	74 805.2
0.4	2.99	80	598.4	20 000	149 610.4
0.5	3.74	90	673.2	30 000	224 415.6
0.6	4.49	100	748.1	40 000	299 220.8
0.7	5.24	200	1 496.1	50 000	374 025.9
0.8	5.98	300	2 244.2	60 000	448 831.1
0.9	6.73	400	2 992.2	70 000	523 636.3
1	7.48	500	3 740.3	80 000	598 441.5
2	14.96	600	4 488.3	90 000	673 246.7
3	22.44	700	5 236.4	100 000	748 051.9
4	29.92	800	5 984.4	200 000	1 496 103.8
5	37.40	900	6 732.5	300 000	2 244 155.7
6	44.88	1000	7 480.5	400 000	2 992 207.6
7	52.36	2000	14 961.0	500 000	3 740 259.5
8	59.84	3000	22 441.6	600 000	4 488 311.4
9	67.32	4000	29 922.1	700 000	5 236 363.3
10	74.81	5000	37 402.6	800 000	5 984 415.2
20	149.6	6000	44 883.1	900 000	6 732 467.1
30	224.4	7000	52 363.6	1 000 000	7 480 519.0
40	299.2				

Cubic Feet in a Given Number of Gallons

Gallons	Cubic feet	Gallons	Cubic feet	Gallons	Cubic feet
1	.134	1 000	133.681	1 000 000	133 680.6
2	.267	2 000	267.361	2 000 000	267 361.1
3	.401	3 000	401.042	3 000 000	401 041.7
4	.535	4 000	534.722	4 000 000	534 722.2
5	.668	5 000	668.403	5 000 000	668 402.8
6	.802	6 000	802.083	6 000 000	802 083.4
7	.936	7 000	935.764	7 000 000	935 763.9
8	1.069	8 000	1 069.444	8 000 000	1 069 444.5
9	1.203	9 000	1 203.125	9 000 000	1 203 125.0
10	1.337	10 000	1 336.806	10 000 000	1 336 805.6

Cubic Feet per Second, Gallons in 24 Hours, etc.

Cubic feet per second....	1/60	1	1.5472	2.2280
Cubic feet per minute....	1	60	92.834	133.681
U. S. gallons per minute.	7.480519	448.83	694.444	1 000
U. S. gallons per 24 hours	10 771.95	646 317	1 000 000	1 440 000
Pounds of water (at 62° F.) per minute............	62.355	3741.3	5788.65	8335.65

Contents in Cubic Feet and United States Gallons of Pipes and Cylinders of Various Inside Diameters and One Foot in Length

(1 gallon = 231 cubic inches. 1 cubic foot = 7.4805 gallons.)

Diameter in inches	For 1 ft. in length		Diameter in inches	For 1 ft. in length		Diameter in inches	For 1 ft. in length	
	Cubic feet, also area in square feet	U. S. gallons		Cubic feet, also area in square feet	U. S. gallons		Cubic feet, also area in square feet	U. S. gallons
¼	.0003	.0025	6¾	.2485	1.859	19	1.969	14.73
5/16	.0005	.0040	7	.2673	1.999	19½	2.074	15.51
⅜	.0008	.0057	7¼	.2867	2.145	20	2.182	16.32
7/16	.0010	.0078	7½	.3068	2.295	20½	2.292	17.15
½	.0014	.0102	7¾	.3276	2.450	21	2.405	17.99
9/16	.0017	.0129	8	.3491	2.611	21½	2.521	18.86
⅝	.0021	.0159	8¼	.3712	2.777	22	2.640	19.75
11/16	.0026	.0193	8½	.3941	2.948	22½	2.761	20.66
¾	.0031	.0230	8¾	.4176	3.125	23	2.885	21.58
13/16	.0036	.0269	9	.4418	3.305	23½	3.012	22.53
⅞	.0042	.0312	9¼	.4667	3.491	24	3.142	23.50
15/16	.0048	.0359	9½	.4922	3.682	25	3 409	25.50
1	.0055	.0408	9¾	.5185	3.879	26	3.687	27.58
1¼	.0085	.0638	10	.5454	4.080	27	3.976	29.74
1½	.0123	.0918	10¼	.5730	4.286	28	4.276	31.99
1¾	.0167	.1249	10½	.6013	4.498	29	4.587	34.31
2	.0218	.1632	10¾	.6303	4.715	30	4.909	36.72
2¼	.0276	.2066	11	.6600	4.937	31	5.241	39.21
2½	.0341	.2550	11¼	.6903	5.164	32	5.585	41.78
2¾	.0412	.3085	11½	.7213	5.396	33	5.940	44.43
3	.0491	.3672	11¾	.7530	5.633	34	6.305	47.16
3¼	.0576	.4309	12	.7854	5.875	35	6.681	49.98
3½	.0668	.4998	12½	.8522	6.375	36	7.069	52.88
3¾	.0767	.5738	13	.9218	6.895	37	7.467	55.86
4	.0873	.6528	13½	.9940	7.436	38	7.876	58.92
4¼	.0985	.7369	14	1.069	7.997	39	8.296	62.06
4½	.1104	.8263	14½	1.147	8.578	40	8.727	65.28
4¾	.1231	.9206	15	1.227	9.180	41	9.168	68.58
5	.1364	1.020	15½	1.310	9.801	42	9.621	71.97
5¼	.1503	1.125	16	1.396	10.44	43	10.085	75.44
5½	.1650	1.234	16½	1.485	11.11	44	10.559	78.99
5¾	.1803	1.349	17	1.576	11.79	45	11.045	82.62
6	.1963	1.469	17½	1.670	12.49	46	11.541	86.33
6¼	.2131	1.594	18	1.767	13.22	47	12.048	90.13
6½	.2304	1.724	18½	1.867	13.96	48	12.566	94.00

To find the capacity of pipes greater than the largest given in the table, look in the table for a pipe of one-half the given size, and multiply its capacity by 4; or one of one-third its size, and multiply its capacity by 9, etc.

To find the weight of water in any of the given sizes, multiply the capacity in cubic feet by $62\frac{1}{2}$ or the capacity in gallons by $8\frac{1}{3}$, or, if a more accurate result is required, by the weight of a cubic foot of water at the actual temperature in the pipe.

Given the dimensions of a cylinder in inches, to find its capacity in U. S. gallons: Square the diameter, multiply by the length and by 0.0034. If d = diameter, l = length, gallons $= \dfrac{d^2 \times 0.7854 \times l}{231} = 0.0034\, d^2 l.$

If D and L are in feet, gallons $= 5.875\, D^2 L.$

Cylindrical Vessels, Tanks and Cisterns

Diameter in Ft. and Ins., Area in Sq. Ft. and Capacity in U. S. Gals. for 1 Ft. in Depth

(1 gallon = 231 cubic inches = 1 cubic foot/7.4805 = 0.13368 cubic foot.)

Diameter, ft.	in.	Area, square feet	Gallons, 1 foot depth	Diameter, ft.	in.	Area, square feet	Gallons, 1 foot depth	Diameter, ft.	in.	Area, square feet	Gallons, 1 foot depth
1	0	.785	5.87	5	8	25.22	188.66	19	0	283.53	2120.9
1	1	.922	6.89	5	9	25.97	194.25	19	3	291.04	2177.1
1	2	1.069	8.00	5	10	26.73	199.92	19	6	298.65	2234.0
1	3	1.227	9.18	5	11	27.49	205.67	19	9	306.35	2291.7
1	4	1.396	10.44	6	0	28.27	211.51	20	0	314.16	2350.1
1	5	1.576	11.79	6	3	30.68	229.50	20	3	322.06	2409.2
1	6	1.767	13.22	6	6	33.18	248.23	20	6	330.06	2469.1
1	7	1.969	14.73	6	9	35.78	267.69	20	9	338.16	2529.6
1	8	2.182	16.32	7	0	38.48	287.88	21	0	346.36	2591.0
1	9	2.405	17.99	7	3	41.28	308.81	21	3	354.66	2653.0
1	10	2.640	19.75	7	6	44.18	330.48	21	6	363.05	2715.8
1	11	2.885	21.58	7	9	47.17	352.88	21	9	371.54	2779.3
2	0	3.142	23.50	8	0	50.27	376.01	22	0	380.13	2843.6
2	1	3.409	25.50	8	3	53.46	399.88	22	3	388.82	2908.6
2	2	3.687	27.58	8	6	56.75	424.48	22	6	397.61	2974.3
2	3	3.976	29.74	8	9	60.13	449.82	22	9	406.49	3040.8
2	4	4.276	31.99	9	0	63.62	475.89	23	0	415.48	3108.0
2	5	4.587	34.31	9	3	67.20	502.70	23	3	424.56	3175.9
2	6	4.909	36.72	9	6	70.88	530.24	23	6	433.74	3244.6
2	7	5.241	39.21	9	9	74.66	558.51	23	9	443.01	3314.0
2	8	5.585	41.78	10	0	78.54	587.52	24	0	452.39	3384.1
2	9	5.940	44.43	10	3	82.52	617.26	24	3	461.86	3455.0
2	10	6.305	47.16	10	6	86.59	647.74	24	6	471.44	3526.6
2	11	6.681	49.98	10	9	90.76	678.95	24	9	481.11	3598.9
3	0	7.069	52.88	11	0	95.03	710.90	25	0	490.87	3672.0
3	1	7.467	55.86	11	3	99.40	743.58	25	3	500.74	3745.8
3	2	7.876	58.92	11	6	103.87	776.99	25	6	510.71	3820.3
3	3	8.296	62.06	11	9	108.43	811.14	25	9	520.77	3895.6
3	4	8.727	65.28	12	0	113.10	846.03	26	0	530.93	3971.6
3	5	9.168	68.58	12	3	117.86	881.65	26	3	541.19	4048.4
3	6	9.621	71.97	12	6	122.72	918.00	26	6	551.55	4125.9
3	7	10.085	75.44	12	9	127.68	955.09	26	9	562.00	4204.1
3	8	10.559	78.99	13	0	132.73	992.91	27	0	572.56	4283.0
3	9	11.045	82.62	13	3	137.89	1031.5	27	3	583.21	4362.7
3	10	11.541	86.33	13	6	143.14	1070.8	27	6	593.96	4443.1
3	11	12.048	90.13	13	9	148.49	1110.8	27	9	604.81	4524.3
4	0	12.566	94.00	14	0	153.94	1151.5	28	0	615.75	4606.2
4	1	13.095	97.96	14	3	159.48	1193.0	28	3	626.80	4688.8
4	2	13.635	102.00	14	6	165.13	1235.3	28	6	637.94	4772.1
4	3	14.186	106.12	14	9	170.87	1278.2	28	9	649.18	4856.2
4	4	14.748	110.32	15	0	176.71	1321.9	29	0	660.52	4941.0
4	5	15.321	114.61	15	3	182.65	1366.4	29	3	671.96	5026.6
4	6	15.90	118.97	15	6	188.69	1411.5	29	6	683.49	5112.9
4	7	16.50	123.42	15	9	194.83	1457.4	29	9	695.13	5199.9
4	8	17.10	127.95	16	0	201.06	1504.1	30	0	706.86	5287.7
4	9	17.72	132.56	16	3	207.39	1551.4	30	3	718.69	5376.2
4	10	18.35	137.25	16	6	213.82	1599.5	30	6	730.62	5465.4
4	11	18.99	142.02	16	9	220.35	1648.4	30	9	742.64	5555.4
5	0	19.63	146.88	17	0	226.98	1697.9	31	0	754.77	5646.1
5	1	20.29	151.82	17	3	233.71	1748.2	31	3	766.99	5737.5
5	2	20.97	156.83	17	6	240.53	1799.3	31	6	779.31	5829.7
5	3	21.65	161.93	17	9	247.45	1851.1	31	9	791.73	5922.6
5	4	22.34	167.12	18	0	254.47	1903.6	32	0	804.25	6016.2
5	5	23.04	172.38	18	3	261.59	1956.8	32	3	816.86	6110.6
5	6	23.76	177.72	18	6	268.80	2010.8	32	6	829.58	6205.7
5	7	24.48	183.15	18	9	276.12	2065.5	32	9	842.39	6301.5

Weight of Water in Foot Lengths of Pipe of Different Inside Diameters

(62.425 pounds per cubic foot.)

Diameter, inches	Water, pounds	Diameter, inches	Water, pounds	Diameter, inches	Water, pounds	Diameter, inches	Water, pounds
1/8	0.0053	3	3.0643	7 3/4	20.450	17	98.397
1/4	0.0213	3 1/8	3.3250	8	21.790	17 1/2	104.27
3/8	0.0479	3 1/4	3.5963	8 1/4	23.174	18	110.31
1/2	0.0851	3 3/8	3.8782	8 1/2	24.599	18 1/2	116.53
5/8	0.1330	3 1/2	4.1708	8 3/4	26.068	19	122.91
3/4	0.1915	3 5/8	4.4741	9	27.579	19 1/2	129.47
7/8	0.2607	3 3/4	4.7879	9 1/4	29.132	20	136.19
1	0.3405	3 7/8	5.1125	9 1/2	30.728	21	150.15
1 1/8	0.4309	4	5.4476	9 3/4	32.366	22	164.79
1 1/4	0.5320	4 1/4	6.1498	10	34.048	23	180.11
1 3/8	0.6437	4 1/2	6.8946	10 1/2	37.537	24	196.11
1 1/2	0.7661	4 3/4	7.6820	11	41.198	25	212.80
1 5/8	0.8991	5	8.5119	11 1/2	45.028	26	230.16
1 3/4	1.0427	5 1/4	9.3844	12	49.028	27	248.21
1 7/8	1.1970	5 1/2	10.299	12 1/2	53.199	28	266.93
2	1.3619	5 3/4	11.257	13	57.540	29	286.34
2 1/8	1.5375	6	12.257	13 1/2	62.052	30	306.43
2 1/4	1.7237	6 1/4	13.300	14	66.733	31	327.20
2 3/8	1.9205	6 1/2	14.385	14 1/2	71.585	32	348.65
2 1/2	2.1280	6 3/4	15.513	15	76.607	33	370.78
2 5/8	2.3461	7	16.683	15 1/2	81.799	34	393.59
2 3/4	2.5748	7 1/4	17.896	16	87.162	35	417.08
2 7/8	2.8142	7 1/2	19.152	16 1/2	92.694	36	441.26

Weights of water in cylinders of the same length are proportional to the squares of the diameters. Therefore, to get weight of cylinder of water one foot long and 60 inches diameter, take from above table weight of water of 30-inch pipe and multiply it by the square of 60 ÷ 30, or the square of two; thus, 306.43 × 4 = 1225.72 = the weight of water in one foot length of a 60-inch pipe.

Number of Barrels (31½ Gallons) in Cylindrical Cisterns and Tanks

(1 barrel = 31½ gallons = $31.5 \times 231/1728 = 4.21094$ cu. ft.; reciprocal = 0.237477.)

Depth in feet	Diameter in feet								
	5	6	7	8	9	10	11	12	13
1	4.663	6.714	9.139	11.937	15.108	18.652	22.569	26.859	31.522
5	23.3	33.6	45.7	59.7	75.5	93.3	112.8	134.3	157.6
6	28.0	40.3	54.8	71.6	90.6	111.9	135.4	161.2	189.1
7	32.6	47.0	64.0	83.6	105.8	130.6	158.0	188.0	220.7
8	37.3	53.7	73.1	95.5	120.9	149.2	180.6	214.9	252.2
9	42.0	60.4	82.3	107.4	136.0	167.9	203.1	241.7	283.7
10	46.6	67.1	91.4	119.4	151.1	186.5	225.7	268.6	315.2
11	51.3	73.9	100.5	131.3	166.2	205.2	248.3	295.4	346.7
12	56.0	80.6	109.7	143.2	181.3	223.8	270.8	322.3	378.3
13	60.6	87.3	118.8	155.2	196.4	242.5	293.4	349.2	409.8
14	65.3	94.0	127.9	167.1	211.5	261.1	316.0	376.0	441.3
15	69.9	100.7	137.1	179.1	226.6	279.8	338.5	402.9	472.8
16	74.6	107.4	146.2	191.0	241.7	298.4	361.1	429.7	504.4
17	79.3	114.1	155.4	202.9	256.8	317.1	383.7	456.6	535.9
18	83.9	120.9	164.5	214.9	271.9	335.7	406.2	483.5	567.4
19	88.6	127.6	173.6	226.8	287.1	354.4	428.8	510.3	598.9
20	93.3	134.3	182.8	238.7	302.2	373.0	451.4	537.2	630.4
	14	15	16	17	18	19	20	21	22
1	36.557	41.966	47.748	53.903	60.431	67.332	74.606	82.253	90.273
5	182.8	209.8	238.7	269.5	302.2	336.7	373.0	411.3	451.4
6	219.3	251.8	286.5	323.4	362.6	404.0	447.6	493.5	541.6
7	255.9	293.8	334.2	377.3	423.0	471.3	522.2	575.8	631.9
8	292.5	335.7	382.0	431.2	483.4	538.7	596.8	658.0	722.2
9	329.0	377.7	429.7	485.1	543.9	606.0	671.5	740.3	812.5
10	365.6	419.7	477.5	539.0	604.3	673.3	746.1	822.5	902.7
11	402.1	461.6	525.2	592.9	664.7	740.7	820.7	904.8	993.0
12	438.7	503.6	573.0	646.8	725.2	808.0	895.3	987.0	1083.3
13	475.2	545.6	620.7	700.7	785.6	875.3	969.9	1069.3	1173.5
14	511.8	587.5	668.5	754.6	846.0	942.6	1044.5	1151.5	1263.8
15	548.4	629.5	716.2	808.5	906.5	1010.0	1119.1	1233.8	1354.1
16	584.9	671.5	764.0	862.4	966.9	1077.3	1193.7	1316.0	1444.4
17	621.5	713.4	811.7	916.4	1027.3	1144.6	1268.3	1398.3	1534.5
18	658.0	755.4	859.5	970.3	1087.8	1212.0	1342.9	1480.6	1624.9
19	694.6	797.4	907.2	1024.2	1148.2	1279.3	1417.5	1562.8	1715.2
20	731.1	839.3	955.0	1078.1	1208.6	1346.6	1492.1	1645.1	1805.5
	23	24	25	26	27	28	29	30	
1	98.666	107.432	116.571	126.083	135.968	146.226	156.858	167.863	
5	493.3	537.2	582.9	630.4	679.8	731.1	784.3	839.3	
6	592.0	644.6	699.4	756.5	815.8	877.4	941.1	1007.2	
7	690.7	752.0	816.0	882.6	951.8	1023.6	1098.0	1175.0	
8	789.3	859.5	932.6	1008.7	1087.7	1169.8	1254.9	1342.9	
9	888.0	966.9	1049.1	1134.7	1223.7	1316.0	1411.7	1510.8	
10	986.7	1074.3	1165.7	1260.8	1359.7	1462.2	1568.6	1678.6	
11	1085.3	1181.8	1282.3	1386.9	1495.6	1608.5	1725.4	1846.5	
12	1184.0	1289.2	1398.8	1513.0	1631.6	1754.7	1882.3	2014.4	
13	1282.7	1396.6	1515.4	1639.1	1767.6	1900.9	2039.2	2182.2	
14	1381.3	1504.0	1632.0	1765.2	1903.6	2047.2	2196.0	2350.1	
15	1480.0	1611.5	1748.6	1891.2	2039.5	2193.4	2352.9	2517.9	
16	1578.7	1718.9	1865.1	2017.3	2175.5	2339.6	2509.7	2685.8	
17	1677.3	1826.3	1981.7	2143.4	2311.5	2485.8	2666.6	2853.7	
18	1776.0	1933.8	2098.3	2269.5	2447.4	2632.0	2823.4	3021.5	
19	1874.7	2041.2	2214.8	2395.6	2583.4	2778.3	2980.3	3189.4	
20	1973.3	2148.6	2321.4	2521.7	2719.4	2924.5	3137.2	3357 3	

Capacities of Rectangular Tanks

U. S. Gallons for Each Foot in Depth (1 cubic foot = 7.4805 U. S. gallons.)

Width of tank	Length of tank										
	2 feet	2 feet 6 inches	3 feet	3 feet 6 inches	4 feet	4 feet 6 inches	5 feet	5 feet 6 inches	6 feet	6 feet 6 inches	7 feet
ft. in.											
2 0	29.92	37.40	44.88	52.36	59.84	67.32	74.81	82.29	89.77	97.25	104.7
2 6	.....	46.75	56.10	65.45	74.80	84.16	93.51	102.86	112.21	121.56	130.9
3 0	.....	.....	67.32	78.54	89.77	100.99	112.21	123.43	134.65	145.87	157.0
3 6	.....	.....	.....	91.64	104.73	117.82	130.91	144.00	157.09	170.18	183.2
4 0	.....	.....	.....	.....	119.69	134.65	149.61	164.57	179.53	194.49	209.4
4 6	.....	.....	.....	.....	.....	151.48	168.31	185.14	201.97	218.80	235.6
5 0	.....	.....	.....	.....	.....	.....	187.01	205.71	224.41	243.11	261.8
5 6	.....	.....	.....	.....	.....	.....	.....	226.28	246.86	267.43	288.0
6 0	.....	.....	.....	.....	.....	.....	.....	.....	269.30	291.74	314.1
6 6	.....	.....	.....	.....	.....	.....	.....	.....	.....	316.05	340.3
7 0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	366.5

Capacities of Rectangular Tanks (Concluded)

U. S. Gallons for Each Foot in Depth (1 cubic foot = 7.4805 U. S. gallons.)

Width of tank	Length of tank									
	7 feet 6 inches	8 feet	8 feet 6 inches	9 feet	9 feet 6 inches	10 feet	10 feet 6 inches	11 feet	11 feet 6 inches	12 feet
ft. in.										
2 0	112.21	119.69	127.17	134.65	142.13	149.61	157.09	164.57	172.05	179.5
2 6	140.26	149.61	158.96	168.31	177.66	187.01	196.36	205.71	215.06	224.41
3 0	168.31	179.53	190.75	202.97	213.19	224.41	235.63	246.86	258.07	269.3
3 6	196.36	209.45	222.54	235.63	248.73	261.82	274.90	288.00	301.09	314.18
4 0	224.41	239.37	254.34	269.30	284.26	299.22	314.18	329.14	344.10	359.06
4 6	252.47	269.30	286.13	302.96	319.79	336.62	353.45	370.28	387.11	403.94
5 0	280.52	299.22	317.92	336.62	355.32	374.03	392.72	411.43	430.13	448.83
5 6	308.57	329.14	349.71	370.28	390.85	411.43	432.00	452.57	473.14	493.71
6 0	336.62	359.06	381.50	403.94	426.39	448.83	471.27	493.71	516.15	538.59
6 6	364.67	388.98	413.30	437.60	461.92	486.23	510.54	534.85	559.16	583.47
7 0	392.72	418.91	445.09	471.27	497.45	523.64	549.81	575.99	602.18	628.36
7 6	420.78	448.83	476.88	504.93	532.98	561.04	589.08	617.14	645.19	673.24
8 0	.....	478.75	508.67	538.59	568.51	598.44	628.36	658.28	688.20	718.12
8 6	.....	.....	540.46	572.25	604.05	635.84	667.63	699.42	731.21	763.00
9 0	.....	.....	.....	605.92	639.58	673.25	706.90	740.56	774.23	807.89
9 6	.....	.....	.....	.....	675.11	710.65	746.17	781.71	817.24	852.77
10 0	.....	.....	.....	.....	.....	748.05	785.45	822.86	860.26	897.66
10 6	.....	.....	.....	.....	.....	.....	824.73	864.00	903.26	942.56
11 0	.....	.....	.....	.....	.....	.....	.....	905.14	946.27	987.43
11 6	.....	.....	.....	.....	.....	.....	.....	.....	989.29	1032.3
12 0	.....	.....	.....	.....	.....	.....	.....	.....	.....	1077.2

Relative Discharging Capacities of Pipe

Actual internal diameter	.269	.364	.493	.622	.824	1.049	1.380	1.610
Nominal internal diameter	**⅛**	**¼**	**⅜**	**½**	**¾**	**1**	**1¼**	**1½**
⅛	1							
¼	2.1	1						
⅜	4.5	2.1	1					
½	8	3.8	1.8	1				
¾	16	8	3.6	2	1			
1	30	14	6.6	3.7	1.8	1		
1¼	60	28	13	7	3.6	2	1	
1½	88	41	19	11	5.3	2.9	1.5	1
2	164	77	36	20	10	5.5	2.7	1.9
2½	255	120	56	31	16	8	4.3	2.9
3	439	206	97	54	27	15	7	5
3½	632	297	139	78	38	21	11	7
4	867	407	191	107	53	29	15	10
4½	1 148	539	253	141	70	38	19	13
5	1 525	716	335	188	93	51	26	17
6	2 414	1 133	531	297	147	80	40	28
7	3 483	1 635	766	428	212	116	58	40
8	4 795	2 251	1 054	590	292	160	80	55
9	6 369	2 990	1 401	783	388	212	107	73
10	8 468	3 976	1 862	1 042	516	282	142	97
11	10 693	5 020	2 352	1 315	651	356	179	122
12	13 292	6 240	2 923	1 635	809	443	223	152
13	17 028	7 994	3 745	2 094	1037	567	286	194
14	20 425	9 589	4 492	2 512	1244	680	343	233
15	24 199	11 361	5 322	2 976	1474	806	406	276
18 O. D.	31 750	14 906	6 982	3 905	1933	1057	533	362
20 O. D.	41 928	19 685	9 221	5 157	2553	1396	703	478
22 O. D.	53 848	25 281	11 842	6 623	3279	1793	903	614
24 O. D.	67 599	31 737	14 866	8 315	4116	2251	1134	771
26 O. D.	83 267	39 093	18 312	10 242	5070	2773	1397	950
28 O. D.	100 932	47 387	22 197	12 415	6146	3361	1693	1152
30 O. D.	120 675	56 655	26 539	14 843	7348	4018	2024	1377
Nominal internal diameter	**⅛**	**¼**	**⅜**	**½**	**¾**	**1**	**1¼**	**1½**
Actual internal diameter	**.269**	**.364**	**.493**	**.622**	**.824**	**1.049**	**1.380**	**1.610**

Relative Discharging Capacities of Pipe (Continued)

Actual internal diameter	2.067	2.469	3.068	3.548	4.026	4.506	5.047	6.065
Nominal internal diameter	2	2½	3	3½	4	4½	5	6
⅛								
¼								
⅜								
½								
¾								
1								
1¼								
1½								
2	1							
2½	1.6	1						
3	2.7	1.7	1					
3½	3.9	2.5	1.4	1				
4	5.3	3.4	2	1.4	1			
4½	7	4.5	2.6	1.8	1.3	1		
5	9	6	3.5	2.4	1.8	1.3	1	
6	15	9	5.5	3.8	2.8	2.1	1.6	1
7	21	14	8	5.5	4	3	2.3	1.4
8	29	19	10.9	7.6	5.5	4.2	3.1	2
9	39	25	14	10	7.3	5.5	4.2	2.6
10	52	33	19	13	10	7.4	5.6	3.5
11	65	42	24	17	12	9.3	7	4.4
12	81	52	30	21	15	12	8.7	5.5
13	104	67	39	27	20	15	11	7
14	125	80	46	32	24	18	13	8.5
15	148	95	55	38	28	21	16	10
18 O. D.	194	124	72	50	37	28	21	13
20 O. D.	256	164	95	66	48	37	27	17
22 O. D.	329	211	123	85	62	47	35	22
24 O. D.	413	265	154	107	78	59	44	28
26 O. D.	509	326	190	132	96	73	55	34
28 O. D.	617	395	230	160	116	88	66	42
30 O. D.	737	473	275	191	139	105	79	50
Nominal internal diameter	2	2½	3	3½	4	4½	5	6
Actual internal diameter	2.067	2.469	3.068	3.548	4.026	4.506	5.047	6.065

Calculations based on the inside diameters of standard pipe, page 22.

Formula

Relative discharge capacity $= \sqrt{\text{inside diameter}^5}$.

Relative Discharging Capacities of Pipe (Continued)

Actual internal diameter	7.023	7.981	8.941	10.020	11.000	12.000	13.250	14.250
Nominal internal diameter	7	8	9	10	11	12	14 O. D.	15 O. D.
1/8								
1/4								
3/8								
1/2								
3/4								
1								
1 1/4								
1 1/2								
2								
2 1/2								
3								
3 1/2								
4								
4 1/2								
5								
6								
7	1							
8	1.3	1						
9	1.8	1.3	1					
10	2.4	1.8	1.3	1				
11	3	2.2	1.7	1.3	1			
12	3.8	2.8	2.1	1.6	1.2	1		
13	4.9	3.6	2.7	2	1.6	1.3	1	
14	5.9	4.3	3.2	2.4	1.9	1.5	1.2	1
15	6.9	5	3.8	2.9	2.3	1.8	1.4	1.2
18 O. D.	9.1	6.6	5	3.7	3	2.4	1.9	1.6
20 O. D.	12	8.7	6.6	5	3.9	3.2	2.5	2.1
22 O. D.	15	11	8.5	6.4	5	4.1	3.2	2.6
24 O. D.	19	14	11	8	6.3	5.1	4	3.3
26 O. D.	24	17	13	9.8	7.8	6.3	4.9	4.1
28 O. D.	29	21	16	12	9.4	7.6	5.9	4.9
30 O. D.	35	25	19	14	11	9.1	7.1	5.9
Nominal internal diameter	7	8	9	10	11	12	13	14
Actual internal diameter	7.023	7.981	8.941	10.020	11.000	12.000	13.250	14.250

Relative Discharging Capacities of Pipe (Concluded)

Actual internal diameter	15.250	17.000	19.000	21.000	23.000	25.000	27.000	29.000
Nominal internal diameter	16 O. D.	18 O. D.	20 O. D.	22 O. D.	24 O. D.	26 O. D.	28 O. D.	30 O. D.
1/8								
1/4								
3/8								
1/2								
3/4								
1								
1 1/4								
1 1/2								
2								
2 1/2								
3								
3 1/2								
4								
4 1/2								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15	1							
18 O. D.	1.3	1						
20 O. D.	1.7	1.3	1					
22 O. D.	2.2	1.7	1.3	1				
24 O. D.	2.8	2.1	1.6	1.3	1			
26 O. D.	3.4	2.6	2	1.5	1.2	1		
28 O. D.	4.2	3.2	2.4	1.9	1.5	1.2	1	
30 O. D.	5	3.8	2.9	2.2	1.8	1.4	1.2	1
Nominal internal diameter	15	18 O. D.	20 O. D.	22 O. D.	24 O. D.	26 O. D.	28 O. D.	30 O. D.
Actual internal diameter	15.250	17.000	19.000	21.000	23.000	25.000	27.000	29.000

Calculations based on the inside diameters of standard pipe, page 22.

Formula

Relative discharge capacity $= \sqrt{\text{inside diameter}^5}$.

Equivalents of Ounces per Square Inch in Inches of Water and Mercury

(Water at 62° F. weighs 62.355 pounds per cubic foot.)

(Specific gravity of mercury at 62° F. = 13.58.)

Ounces per square inch	Pound per square inch	Inches of water	Inches of mercury
0.25	.015625	0.433	.0319
0.50	.03125	0.866	.0638
1	.06250	1.732	.1275
2	.12500	3.464	.2551
3	.18750	5.196	.3826
4	.25000	6.928	.5102
5	.31250	8.660	.6377
6	.37500	10.392	.7653
7	.43750	12.124	.8928
8	.50000	13.856	1.020
9	.56250	15.588	1.148
10	.62500	17.320	1.275
11	.68750	19.052	1.403
12	.75000	20.784	1.531
13	.81250	22.516	1.658
14	.87500	24.248	1.786
15	.93750	25.980	1.913
16	1.00000	27.712	2.041

Equivalents of Pounds per Square Inch in Inches and Feet of Water and Mercury

(Water at 62° F. weighs 62.355 pounds per cubic foot.)

(Specific gravity of mercury at 62° F. = 13.58.)

Pounds per square inch	Inches of water	Feet of water	Inches of mercury	Feet of mercury
1	27.71	2.31	2.041	.1701
2	55.42	4.62	4.081	.3401
3	83.14	6.93	6.122	.5102
4	110.85	9.24	8.163	.6802
5	138.56	11.55	10.20	.8503
6	166.27	13.86	12.24	1.020
7	193.99	16.17	14.28	1.190
8	221.70	18.47	16.33	1.360
9	249.41	20.78	18.37	1.531
10	277.12	23.09	20.41	1.701
11	304.84	25.40	22.45	1.871
12	332.55	27.71	24.49	2.041
13	360.26	30.02	26.53	2.211
14	387.97	32.33	28.57	2.381
14.7	407.37	33.95	30.00	2.500
15	415.68	34.64	30.61	2.551
16	443.40	36.95	32.65	2.721
17	471.11	39.26	34.69	2.891
18	498.82	41.57	36.73	3.061
19	526.53	43.88	38.77	3.231
20	554.25	46.19	40.81	3.401
21	581.96	48.50	42.85	3.571
22	609.67	50.81	44.89	3.741
23	637.38	53.12	46.94	3.911
24	665.10	55.42	48.98	4.081
25	692.81	57.73	51.02	4.251

Conversion Table

BASIS: 1 cubic foot of water at 39.1° F. = 62.425 pounds.
1 U. S. gallon = 231 cubic inches.
1 imperial gallon = 277.274 cubic inches.*

U. S. gallon	=	231.000000 cubic inches.
U. S. gallon	=	0.133681 cubic foot.
U. S. gallon	=	0.833111 imperial gallon.
U. S. gallon	=	3.785434 liters.
U. S. gallon of water at 39.1° F.	=	8.345009 pounds.
Imperial gallon	=	277.274000 cubic inches.*
Imperial gallon	=	0.160459 cubic foot.
Imperial gallon	=	1.200320 U. S. gallons.
Imperial gallon	=	4.543734 liters.
Imperial gallon of water at 39.1° F.	=	10.016684 pounds.*
Cubic foot	=	7.480519 U. S. gallons.
Cubic foot	=	6.232103 imperial gallons.
Cubic foot	=	28.317016 liters.
Cubic foot of water at 39.1° F.	=	62.425000 pounds.
Cubic foot of water at 39.1° F.	=	0.031212 ton.
Cubic inch	=	0.004329 U. S. gallon.
Cubic inch	=	0.003607 imperial gallon.
Cubic inch	=	0.016387 liter.
Cubic inch of water at 39.1° F.	=	0.036126 pound.
Cubic inch of water at 39.1° F.	=	0.578009 ounce.
Pound of water at 39.1° F.	=	27.681217 cubic inches.
Pound of water at 39.1° F.	=	0.016019 cubic foot.
Pound of water at 39.1° F.	=	0.119832 U. S. gallon.
Pound of water at 39.1° F.	=	0.099833 imperial gallon.
Pound of water at 39.1° F.	=	0.453617 liter.
Liter	=	0.264170 U. S. gallon.
Liter	=	0.220083 imperial gallon.
Liter	=	61.023378 cubic inches.
Liter	=	0.035314 cubic foot.
Liter of water at 39.1° F.	=	2.204505 pounds.

* The British imperial gallon is usually defined as being equal to 277.274 cubic inches, or 10 pounds of pure water at the temperature of 62° F. when the barometer is at 30 inches.

CONVENIENT EQUIVALENTS

1 second-foot equals 40 California miner's inches. (Law of March 23, 1901.)

1 second-foot equals 38.4 Colorado miner's inches.

1 second-foot equals 7.48 United States gallons per second; equals 448.8 gallons per minute; equals 646 317 gallons per day.

1 second-foot equals 6.23 British imperial gallons per second.

1 second-foot for one year covers one square mile 1.131 feet deep; 13.57 inches deep.

1 second-foot for one year equals 31 536 000 cubic feet.

1 second-foot equals about one acre-inch per hour.

1 second-foot falling 10 feet equals 1.136 horse-power.

100 California miner's inches equal 18.7 United States gallons per second.

100 California miner's inches equal 96.0 Colorado miner's inches.

100 California miner's inches for one day equal 4.96 acre-feet.

100 Colorado miner's inches equal 2.60 second-feet.

100 Colorado miner's inches equal 19.5 United States gallons per second.

100 Colorado miner's inches equal 104 California miner's inches.

100 Colorado miner's inches for one day equal 5.17 acre-feet.

100 United States gallons per minute equal 0.223 second-foot.

100 United States gallons per minute for one day equal 0.442 acre-foot.

1 000 000 United States gallons per day equal 1.55 second-feet.

1 000 000 United States gallons equal 3.07 acre-feet.

1 000 000 cubic feet equal 22.96 acre-feet.

1 acre-foot equals 325 851 gallons.

1 inch deep on 1 square mile equals 2 323 200 cubic feet.

1 inch deep on 1 square mile equals .0737 second-foot per year.

GAS

Physical Properties of Gases

Flow of Gas in Pipes — Low Pressure

Flow of Gas in Pipes — High Pressure

PHYSICAL PROPERTIES OF GASES

(From Kent's Mechanical Engineers' Pocket Book.)

When a mass of gas is inclosed in a vessel it exerts a pressure against the walls. This pressure is uniform on every square inch of the surface of the vessel; also, at any point in the fluid mass the pressure is the same in every direction.

In small vessels containing gases the increase of pressure due to weight may be neglected, since all gases are very light; but where liquids are concerned, the increase in pressure due to their weight must always be taken into account.

Expansion of Gases; Mariotte's Law. The volume of a gas diminishes in the same ratio as the pressure upon it is increased, if the temperature is unchanged.

This law, by experiment, is found to be very nearly true for all gases, and is known as Boyle's or Mariotte's law.

If p = pressure at a volume v, and p_1 = pressure at a volume v_1, $p_1v_1 = pv$; $p_1 = \frac{v}{v_1} p$; pv = a constant, C.

The constant, C, varies with the temperature, everything else remaining the same.

Air compressed by a pressure of seventy-five atmospheres has a volume about 2 per cent less than that computed from Boyle's law, but this is the greatest divergence that is found below 160 atmospheres pressure.

Law of Charles. The volume of a perfect gas at a constant pressure is proportional to its absolute temperature. If v_0 be the volume of a gas at 32° F., and v_1 the volume at any other temperature, t_1, then

$$v_1 = v_0\left(\frac{t_1 + 459.2}{491.2}\right); \quad v_1 = \left(1 + \frac{t_1 - 32^\circ}{491.2}\right)v_0,$$

or,

$$v_1 = [1 + 0.002036\,(t_1 - 32^\circ)]\,v_0.$$

If the pressure also changes from p_0 to p_1,

$$v_1 = v_0\frac{p_0}{p_1}\left(\frac{t_1 + 459.2}{491.2}\right).$$

The Densities of the elementary gases are simply proportional to their atomic weights. The density of a compound gas, referred to hydrogen as 1, is one-half its molecular weight; thus the relative density of CO_2 is $\frac{1}{2}(12 + 32) = 22$.

Avogadro's Law. Equal volumes of all gases, under the same conditions of temperature and pressure, contain the same number of molecules.

To find the weight of a gas in pounds per cubic foot at 32° F., multiply half the molecular weight of the gas by 0.00559. Thus 1 cubic foot of marsh-gas, CH_4,

$$= \frac{1}{2}(12 + 4) \times 0.00559 = 0.0447 \text{ pound.}$$

When a certain volume of hydrogen combines with one-half its volume of oxygen, there is produced an amount of water vapor which will occupy the same volume as that which was occupied by the hydrogen gas when at the same temperature and pressure.

Saturation Point of Vapors. A vapor that is not near the saturation point behaves like a gas under changes of temperature and pressure; but if it is sufficiently compressed or cooled, it reaches a point where it begins to condense; it then no longer obeys the same laws as a gas, but its pressure cannot be increased by diminishing the size of the vessel containing it, but remains constant, except when the temperature is changed. The only gas that can prevent a liquid evaporating seems to be its own vapor.

Dalton's Law of Gaseous Pressures. Every portion of a mass of gas inclosed in a vessel contributes to the pressure against the sides of the vessel the same amount that it would have exerted by itself had no other gas been present.

Mixtures of Vapors and Gases. The pressure exerted against the interior of a vessel by a given quantity of a perfect gas inclosed in it is the sum of the pressures which any number of parts into which such quantity might be divided would exert separately, if each were inclosed in a vessel of the same bulk alone, at the same temperature. Although this law is not exactly true for any actual gas, it is very nearly true for many. Thus if 0.080728 pound of air at 32° F., being inclosed in a vessel of 1 cubic foot capacity, exerts a pressure of one atmosphere, or 14.7 pounds, on each square inch of the interior of the vessel, then will each additional 0.080728 pound of air which is inclosed, at 32° F., in the same vessel, produce very nearly an additional atmosphere of pressure. The same law is applicable to mixtures of gases of different kinds. For example, 0.12344 pound of carbonic-acid gas, at 32° F., being inclosed in a vessel of one cubic foot capacity, exerts a pressure of one atmosphere; consequently, if 0.080728 pound of air and 0.12344 pound of carbonic-acid, mixed, be inclosed at the temperature of 32° F., in a vessel of one cubic foot capacity, the mixture will exert a pressure of two atmospheres. As a second example: let 0.080728 pound of air, at 212° F., be inclosed in a vessel of one cubic foot; it will exert a pressure of

$$\frac{212 + 459.2}{32 + 459.2} = 1.366 \text{ atmospheres.}$$

Let 0.03797 pound of steam, at 212° F., be inclosed in a vessel of one cubic foot; it will exert a pressure of one atmosphere. Consequently,

if 0.080728 pound of air and 0.03797 pound of steam be mixed and inclosed together, at 212° F., in a vessel of one cubic foot, the mixture will exert a pressure of 2.366 atmospheres. It is a common but erroneous practice, in elementary books on physics, to describe this law as constituting a difference between mixed and homogeneous gases; whereas it is obvious that for mixed and homogeneous gases the law of pressure is exactly the same, viz., that the pressure of the whole of a gaseous mass is the sum of the pressures of all its parts. This is one of the laws of mixture of gases and vapors.

A second law is that the presence of a foreign gaseous substance in contact with the surface of a solid or liquid does not affect the density of the vapor of that solid or liquid unless there is a tendency to chemical combination between the two substances, in which case the density of the vapor is slightly increased.

If 0.591 pound of air = 1 cubic foot at 212° F. and atmospheric pressure is contained in a vessel of 1 cubic foot capacity, and water at 212° F. is introduced, heat at 212° F. being furnished by a steam jacket, the pressure will rise to two atmospheres.

If air is present in a condenser along with water vapor, the pressure is that due to the temperature of the vapor plus that due to the quantity of air present

Flow of Gases. By the principle of the conservation of energy, it may be shown that the velocity with which a gas under pressure will escape into a vacuum is inversely proportional to the square root of its density; that is, oxygen, which is sixteen times as heavy as hydrogen, would, under exactly the same circumstances, escape through an opening only one-fourth as fast as the latter gas.

Absorption of Gases by Liquids. Many gases are readily absorbed by water. Other liquids also possess this power in a greater or less degree. Water will, for example, absorb its own volume of carbonic-acid gas, 430 times its volume of ammonia, 2⅓ times its volume of chlorine, and only about 1/20 of its volume of oxygen.

The weight of gas that is absorbed by a given volume of liquid is proportional to the pressure. But as the volume of a mass of gas is less as the pressure is greater, the volume which a given amount of liquid can absorb at a certain temperature will be constant, whatever the pressure. Water, for example, can absorb its own volume of carbonic-acid gas at atmospheric pressure; it will also dissolve its own volume if the pressure is twice as great, but in that case the gas will be twice as dense, and consequently twice the weight of gas is dissolved.

FLOW OF GAS IN PIPES—LOW PRESSURE

The following formulæ are intended for low-pressure distribution of gas, with comparatively small differences between the initial and final pressures.

Pole's Formula, $Q = 1350 \sqrt{\frac{d^5h}{sl}}.$

Molesworth's Formula, $Q = 1000 \sqrt{\frac{d^5h}{sl}}.$

Gill's Formula, $Q = 1291 \sqrt{\frac{d^5h}{s(l+d)}}.$

Where Q = quantity of gas discharged in cubic feet per hour.
d = inside diameter of pipe in inches.
h = pressure in inches of water.
s = specific gravity of gas, air being 1.
l = length of main in yards.

The formula of Gill is said to be based on experimental data, and to make allowance for obstructions by tar, water, and other bodies tending to check the flow of gas through the pipe.

An experiment made by Mr. Clegg, in London, with a 4-inch pipe, 6 miles long, pressure 3 inches of water, specific gravity of gas 0.398, gave a discharge into the atmosphere of 852 cubic feet per hour, after a correction of 33 cubic feet was made for leakage. Substituting this value for Q in the formula $Q = C \sqrt{\frac{d^5h}{sl}}$, we find the coefficient C to be 997, which corresponds very closely with the formula given by Molesworth.

Maximum Supply of Gas Through Pipes in Cubic Feet per Hour, Specific Gravity being Taken at 0.45, Calculated from the Formula

$$Q = 1000 \sqrt{d^5h \div sl}. \quad \text{(Molesworth)}$$

Length of Pipe = 10 Yards

Inside diameter of pipe in inches	Pressure by the water-gage in inches									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
⅜	13	18	22	26	29	31	34	36	38	41
½	26	37	46	53	59	64	70	74	79	83
¾	73	103	126	145	162	187	192	205	218	230
1	149	211	258	298	333	365	394	422	447	471
1¼	260	368	451	521	582	638	689	737	781	823
1½	411	581	711	821	918	1006	1082	1162	1232	1299
2	843	1192	1460	1686	1886	2066	2231	2385	2530	2667

Length of Pipe = 100 Yards

Inside diameter of pipe in inches	Pressure by the water-gage in inches										
	0.1	0.2	0.3	0.4	0.5	0.75	1.0	1.25	1.5	2.0	2.5
½	8	12	14	17	19	23	26	29	32	36	42
¾	23	32	42	46	51	63	73	81	89	103	115
1	47	67	82	94	105	129	149	167	183	211	236
1¼	82	116	143	165	184	225	260	291	319	368	412
1½	130	184	225	260	290	356	411	459	503	581	649
2	267	377	462	533	596	730	843	943	1033	1193	1333
2½	466	659	807	932	1042	1276	1473	1647	1804	2083	2329
3	735	1039	1270	1470	1643	2012	2323	2598	2846	3286	3674
3½	1080	1528	1871	2161	2416	2958	3416	3820	4184	4831	5402
4	1508	2133	2613	3017	3373	4131	4770	5333	5842	6746	7542

Length of Pipe = 1000 Yards

Inside diameter of pipe in inches	Pressure by the water-gage in inches						
	0.5	0.75	1.0	1.5	2.0	2.5	3.0
1	33	41	47	58	67	75	82
1½	92	113	130	159	184	205	226
2	189	231	267	327	377	422	462
2½	329	403	466	571	659	737	807
3	520	636	735	900	1039	1162	1273
4	1067	1306	1508	1847	2133	2385	2613
5	1863	2282	2635	3227	3727	4167	4564
6	2939	3600	4157	5091	5879	6573	7200

Length of Pipe = 5000 Yards

Inside diameter of pipe in inches	Pressure by the water-gage in inches				
	1.0	1.5	2.0	2.5	3.0
2	119	146	169	189	207
3	329	402	465	520	569
4	675	826	955	1 067	1 168
5	1 179	1 443	1 667	1 863	2 041
6	1 859	2 277	2 629	2 939	3 220
7	2 733	3 347	3 865	4 321	4 734
8	3 816	4 674	5 397	6 034	6 610
9	5 123	6 274	7 245	8 100	8 873
10	6 667	8 165	9 428	10 541	11 547
12	10 516	12 880	14 872	16 628	18 215

Dr. A. C. Humphreys says his experience goes to show that these tables give too small a flow, but it is difficult to accurately check the tables, on account of the extra friction introduced by rough pipes, bends, etc. For bends, one rule is to allow 1/42 of an inch pressure for each right-angle bend.

Where there is apt to be trouble from frost it is well to use no service of less diameter than 3/4 inch, no matter how short it may be. In extremely cold climates this is now often increased to 1 inch, even for a single lamp. The best practice in the United States now condemns any service less than 3/4 inch.

Table Showing the Correct Sizes of House Pipes for Different Lengths of Pipes and Number of Outlets

(Denver Gas and Electric Company)

Number of outlets	Length of pipe in feet								
	3/8-inch pipe	1/2-inch pipe	3/4-inch pipe	1-inch pipe	1 1/4-inch pipe	1 1/2-inch pipe	2-inch pipe	2 1/2-inch pipe	3-inch pipe
1	20	30	50	70	100	150	200	300	400
2	......	27	50	70	100	150	200	300	400
3	......	12	50	70	100	150	200	300	400
4	......	......	50	70	100	150	200	300	400
5	......	......	33	70	100	150	200	300	400
6	......	......	24	70	100	150	200	300	400
8	......	......	13	50	100	150	200	300	400
10	......	......	......	35	100	150	200	300	400
13	......	......	......	21	60	150	200	300	400
15	......	......	......	16	45	120	200	300	400
20	......	......	......	......	27	65	200	300	400
25	......	......	......	......	17	42	175	300	400
30	......	......	......	......	12	30	120	300	400
35	......	......	......	......	......	22	90	270	400
40	......	......	......	......	......	17	70	210	400
45	......	......	......	......	......	13	55	165	400
50	......	......	......	......	......	......	45	135	330
65	......	......	......	......	......	......	27	80	200
75	......	......	......	......	......	......	20	60	150
100	......	......	......	......	......	......	......	33	80
125	......	......	......	......	......	......	......	22	50
150	......	......	......	......	......	......	......	15	35
175	......	......	......	......	......	......	......	......	28
200	......	......	......	......	......	......	......	......	21
225	......	......	......	......	......	......	......	......	17
250	......	......	......	......	......	......	......	......	14

In this table the quantity of gas the piping may be called on to convey is stated in terms of 3/8 inch outlets on the assumption that each

outlet requires a supply of 10 cubic feet per hour. The aim of the table is to have the loss in pressure not exceed 1/10 inch water pressure in 30 feet.

In using the table the following rules should be observed:

In figuring out the size of pipe, always start at the extremities of the system and work toward the meter.

Gas should not be supplied from a smaller to a larger size pipe.

If the exact number of outlets given cannot be found in the table, take the next larger number. For example, if 17 outlets are required, work with the next larger number in the table, which is 20. Or, if, for the number of outlets given, the exact length which feeds these outlets cannot be found in the table, the next larger length corresponding to the outlets given must be taken to determine the size of pipe required. Thus if there are 8 outlets to be fed through 55 feet of pipe, the next larger than 55 in the 8 outlet line in the table, which is 100, should be used. As this is in the 1¼ inch column, that size pipe would be required.

For any given number of outlets, a smaller size should not be used than the smallest size that contains a figure in the table for that number of outlets. Thus, to feed 15 outlets, no smaller size pipe than 1 inch may be used, no matter how short the section of pipe may be.

In any continuous run from an extremity to the meter, there may not be used a longer length of any size pipe than found in the table for that size, as 50 feet of ¾ inch, 70 feet of 1 inch, etc. If any one section would exceed the limit length, it must be made of larger pipe.

If any outlet is larger than ⅜ inch it must be counted as more than one, in accordance with the following table:

Size of outlet (inches)	½	¾	1	1¼	1½	2	2½	3
Value in table	2	4	7	11	16	28	44	64

FLOW OF GAS IN PIPES — HIGH PRESSURE

The formulæ given on page 317 do not take account of the varying density and volume of the gas when subjected to different pressures; they are applicable, therefore, only to low-pressure distribution where the difference in pressure is measured in inches of water head. Under the vastly different conditions connected with high pressure distribution, where the differences between initial and final pressures are so great as to cause a material alteration in the volume of the gas, the error involved in their use is great.

Mariotte's law states that the volume of a gas varies inversely with the pressure to which it is subjected. If the pressure be doubled the gas will be compressed to half its former volume. When we consider the high pressure at which gas is now being distributed in many places, we may appreciate the disturbances which this degree of compression introduces into a formula designed for use under far different conditions.

Then there is also the process of expansion continually going on, the volume increasing as the gas travels farther away from the point at which

the initial pressure is applied. Suppose a quantity of gas is passed through a pipe at an initial pressure of 20 pounds per square inch and discharged at 1 pound per square inch, the consequential expansion represents a certain amount of work, and this factor must, in all cases, be taken into account, to whatever degree it has been operating.

The common form of the formula for flow of gas in long pipes under high pressure is

$$Q = c\sqrt{\frac{(P_1^2 - P_2^2)\,d^5}{ls}}$$

where Q = discharge in cubic feet per hour at atmospheric pressure.
P_1 = absolute initial pressure in pounds per square inch.
P_2 = absolute final pressure in pounds per square inch.
d = inside diameter of pipe in inches.
l = length of pipe line in feet.
s = specific gravity of gas, air being 1.
c = coefficient, which is variously given in the different formulæ.

The expression $(P_1^2 - P_2^2)$ may be replaced by $(P_1 + P_2)(P_1 - P_2)$.

William Cox (Am. Mach., Mar. 20, 1902) gives the formula in the form

$$Q = 3000\sqrt{\frac{(P_1^2 - P_2^2)\,d^5}{l}} \text{ when } s = 0.65.$$

E. A. Rix, in a paper on the "Compression and Transmission of Illuminating Gas," read before the Pacific Coast Gas Association, 1905, gives for the discharge per minute,

$$q = \frac{44.66}{\sqrt{s}}\sqrt{\frac{(P_1^2 - P_2^2)\,d^5}{l}},$$

from which the discharge per hour would be

$$Q = \frac{2680}{\sqrt{s}}\sqrt{\frac{(P_1^2 - P_2^2)\,d^5}{l}}.$$

Forrest M. Towl gives

$$Q = C\sqrt{\frac{(P_1^2 - P_2^2)\,d^5}{L}},$$

L being given in miles instead of feet. The value of C for air is 38.28 and for gas having a specific gravity of 0.59 is 50.

The Pittsburgh formula for discharge is,

$$Q = 3450\sqrt{\frac{(P_1^2 - P_2^2)\,d^5}{l}} \text{ when } s = 0.60.$$

Since the velocity, and therefore the discharge varies inversely as the square root of the density, all of these formulæ may be transformed into the general form given above,

$$Q = c\sqrt{\frac{(P_1^2 - P_2^2)\,d^5}{ls}},$$

the value of c derived from the different formulæ being as follows:

Cox	2419
Pittsburgh	2672
Rix	2680
Towl	2782

Oliphant's Formula. A formula determined by F. H. Oliphant for the discharge of gas when the specific gravity is 0.60, is

$$Q = 42\,a\sqrt{\frac{P_1^2 - P_2^2}{L}},$$

where Q = discharge in cubic feet per hour at atmospheric pressure.
P_1 = initial pressure in pounds per square inch (absolute).
P_2 = final pressure in pounds per square inch (absolute).
L = length of main in miles.
a = coefficient (see table below).

For gas of any other specific gravity, s, multiply the discharge by $\sqrt{\frac{0.60}{s}}$. For temperature of flowing gas when observed above 60° F. deduct 1 per cent for each 5°, and add a like amount for temperatures less than 60° F.

According to Oliphant, the discharge is not strictly proportional to $\sqrt{d^5}$. Using a coefficient of unity for 1 inch pipe he gives $a = \sqrt{d^5} + \frac{d^3}{30}$.

Values of Coefficient "a"

Inside diameter, inches	a	Inside diameter, inches	a	Inside diameter, inches	a
¼	.0317	3	16.5	12	556
½	.1810	4	34.1	16	1160
¾	.5012	5	60	18	1570
1	1.00	5⅝	81	20	2055
1½	2.93	6	95	24	3285
2	5.92	8	198	30	5830
2½	10.37	10	350	36	9330

For 15 inch Outside Diameter Pipe, 14¼ inches Inside Diameter, a = 863.
For 16 inch Outside Diameter Pipe, 15¼ inches Inside Diameter, a = 1025.
For 18 inch Outside Diameter Pipe, 17¼ inches Inside Diameter, a = 1410.
For 20 inch Outside Diameter Pipe, 19¼ inches Inside Diameter, a = 1860.

Unwin's Formula. Professor Unwin in a paper read before the British Institution of Gas Engineers in 1904, suggested the following formula, which takes into account the changes of volume and density,

$$Q = \frac{\pi}{4} D^2 u_2 = \frac{\pi}{4} \frac{P_1}{P_2} D^2 u_1,$$

where Q = discharge in cubic feet per second measured at pressure P_2.
D = diameter of pipe in feet.
u_1 = velocity in feet per second at the inlet of the pipe.
u_2 = velocity in feet per second at the outlet of the pipe.
P_1 = pressure at the inlet of the pipe (absolute).
P_2 = pressure at the outlet of the pipe (absolute).

The value of the velocity is obtained from the following formula,

$$u_1 = 468 \sqrt{\frac{D\ (P_1^2 - P_2^2)}{cslP_1^2}},$$

where, in addition to the notation given above,

s = specific gravity of gas.
l = length of pipe in feet.
c = coefficient of friction which may be obtained from the formula

$$c = 0.0044 \left(1 + \frac{1}{7D}\right).$$

Comparison of Formulæ. That these formulæ give diverse results is shown by the following example. Suppose it is required to find the discharge per hour of an 8 inch pipe line having an intake pressure of 200 pounds gage and a discharge pressure of 25 pounds gage, the length being 20 miles, and the specific gravity of the gas being 0.60. The following results are obtained, the discharge being given in cubic feet at atmospheric pressure.

Cox Formula	367 000 cubic feet per hour.
Unwin Formula	374 700 cubic feet per hour.
Oliphant Formula	392 400 cubic feet per hour.
Pittsburgh Formula	405 500 cubic feet per hour.
Rix Formula	406 700 cubic feet per hour.
Towl Formula	422 100 cubic feet per hour.

The results given above by the various formulæ agree within 7 per cent of the average of results. The rules most generally accepted are the Oliphant and Pittsburgh formulæ. It is understood that all the formulæ quoted apply to straight pipes laid perfectly level. Any deviation from these conditions will of course affect the amount of discharge.

Since the quantity of gas discharged varies as the square root of the difference of the squares of the initial and final pressures, it is evident that as the initial pressure is increased, the final pressure being fixed

the discharge becomes more and more in direct ratio to the increase in pressure. Thus by increasing the pressure from 100 to 200 pounds gage, pressure of discharge being 5 pounds, the quantity of gas transmitted is increased 89 per cent.

Effect of Bends and Fittings. The effect of a bend or sharp angle in a pipe is to reduce the kinetic energy of the gas and, because of the increased friction, to retard the velocity of the gas. It is found that these disturbing influences vary to a great extent with the character of the bend. The resistance offered is least when the radius of the bend is equal to five times the radius of the pipe. The most convenient way of stating the resistance offered by bends is in terms of equivalent length of straight pipe which offers the same resistance to flow as the extra resistance due to the bend. A formula given for this equivalent length is

$$L = 12.85\left(\frac{r}{R}\right)^{0.83} l,$$

where L = equivalent length in feet.
r = radius of pipe.
R = radius of curve.
l = length of curve in feet measured along the center line.

The resistance of a bend whose radius is five times the radius of the pipe, that is $\frac{r}{R} = .2$, is equal to the resistance of $3.38\ l$.

The reduction of pressure produced by elbows, tees and globe valves is also taken account of by the addition of an equivalent length to the length of straight pipe. The following table shows the additional length required to equal the friction due to globe valves. For elbows and tees take ⅔ of the value given in the table.

Diameter of pipe in inches	Additional length in feet	Diameter of pipe in inches	Additional length in feet
1	2	7	44
1½	4	8	53
2	7	10	70
2½	10	12	88
3	13	15	115
3½	16	18	143
4	20	20	162
5	28	22	181
6	36	24	200

Adiabatic Compression of Natural Gas

The following table and the curve, Fig. 130, on page 325, give the rise in temperature due to the adiabatic compression of natural gas. P_1 is the absolute initial and P_2 the absolute final pressure, $\frac{P_2}{P_1}$ being therefore the ratio of compression. The initial temperature of the gas is assumed to be 60° F.

$\frac{P_2}{P_1}$	Rise in temperature °F.	$\frac{P_2}{P_1}$	Rise in temperature °F.	$\frac{P_2}{P_1}$	Rise in temperature °F.
1.	0°	6	238°	14.	386°
1.5	47	6.5	251	16.	412
2	82	7	263	18	435
2.5	110	7.5	274	20.	456
3.	135	8.	285	25.	503
3.5	157	8.5	296	30.	543
4.	177	9.	305	35.	578
4.5	194	10.	324	40.	609
5.	210	11.	341	45.	638
5.5	224	12.	357	50.	664

RISE IN TEMPERATURE °F.

RATIO OF COMPRESSION $\frac{P_2}{P_1}$

Fig. 130

STEAM

Properties

Superheated Steam

Flow of Steam

Loss of Heat from Steam Pipes

STEAM

The Temperature of Steam in contact with water depends upon the pressure under which it is generated. At the ordinary atmospheric pressure (14.7 pounds per square inch) its temperature is 212° F. As the pressure is increased, as when steam is generated in a closed vessel, its temperature, and that of the water in its presence, increases.

Saturated Steam is steam in its normal state, that is, steam whose temperature is that due to its pressure; by which is meant steam at the same temperature as that of the water from which it was generated and upon which it rests.

Superheated Steam is steam at a temperature above that due to its pressure.

Dry Steam is steam which contains no moisture. It may be either saturated or superheated.

Wet Steam is steam containing free moisture in the form of spray or mist. It has the same temperature as dry saturated steam of the same pressure.

Water introduced into superheated steam will be vaporized until the steam becomes saturated, and its temperature becomes that due to its pressure. Cold water, or water at a lower temperature than that of the steam, introduced into saturated steam, will condense some of it, thus lowering both the temperature and pressure of the rest until the temperature again equals that due to its pressure.

The Heat-unit, or British Thermal Unit. The old definition of the heat-unit (Rankine), viz., the quantity of heat required to raise the temperature of 1 pound of water 1° F., at or near its temperature of maximum density (39.1° F.), is now no longer used. Peabody defines it as the heat required to raise a pound of water from 62° to 63° F., and Marks and Davis as $\frac{1}{180}$ of the heat required to raise 1 pound of water from 32° to 212° F. By Peabody's definition the heat required to raise 1 pound of water from 32° to 212° is 180.3 instead of 180 units, and the heat of vaporization at 212° is 969.7 instead of 970.4 units.

The Total Heat of the Water is the number of British thermal units needed to raise one pound of water from 32° F. to the boiling point, under the given pressure.

The Latent Heat of Steam or Heat of Vaporization is the number of British thermal units required to convert one pound of water, at the boiling point, into steam of the same temperature.

The Total Heat of Saturated Steam is the number of heat-units required to raise a pound of water from 32° F. to the boiling point, at the given pressure, plus the number required to convert the water at that temperature into steam of the same temperature.

The total heat in steam (above 32°) includes three elements:

First. The heat required to raise the temperature of the water to the temperature of the steam.

Second. The heat required to evaporate the water at that temperature, called internal latent heat.

Third. The latent heat of volume, or the external work done by the steam in making room for itself against the pressure of the superincumbent atmosphere (or surrounding steam if enclosed in a vessel).

The sum of the last two elements is the latent heat of steam.

The following shows the heat required to generate one pound of steam from water at 32° F.:

			Heat-units
Sensible heat, to raise the water from 32° to 212°	=		180.0
Latent heat, 1, of the formation of steam at 212°	=	897.6	
2, of expansion against the atmospheric pressure, 2116 pounds per square foot × 26.79 cubic feet = 56 688 foot-pounds ÷ 778	=	72.8	970.4
Total heat above 32° F.....			1150.4

Specific Heat of Saturated Steam. When a unit weight of saturated steam is increased in temperature and in pressure, the volume decreasing so as to keep it saturated, the specific heat is negative, and decreases as the temperature increases.

Volume of Saturated Steam. The values of specific volume of saturated steam as given in the Properties of Saturated Steam are computed by Clapyron's equation.

Absolute Zero. The value of the absolute zero has been variously given as from 459.2 to 460.66 degrees below the Fahrenheit zero. Marks and Davis, comparing the results of Berthelot (1903), Buckingham (1907), and Rose-Innes (1908), give as the most probable value −459.64° F. The value −460° is close enough for all engineering calculations.

The Mechanical Equivalent of Heat. The value generally accepted, based on Rowland's experiments, is 778 foot-pounds. Marks and Davis give the value 777.52 standard foot-pounds, based on later experiments, and on the value of g = 980.665 centimeters per second^2 = 32.174 feet per second^2, fixed by international agreement (1901). These values of the absolute zero and of the mechanical equivalent of heat have been used by Marks and Davis in the computation of their steam tables. In refined investigations involving the value of the mechanical equivalent of heat, the value of g for the latitude in which the experiments are made must be considered.

Properties of Saturated Steam

(Condensed by Kent from Marks and Davis's Steam Tables.)

Vacuum, inches of mercury	Absolute pressure, pounds per square inch	Temperature, Fahrenheit	Total heat above 32° F. In the water h, heat-units	Total heat above 32° F. In the steam H, heat-units	Latent heat $L=H-h$, heat-units	Volume, cubic feet in 1 pound of steam	Weight of 1 cubic foot steam, pound	Entropy of the water	Entropy of evaporation
29.74	0.0886	32	0.00	1073.4	1073.4	3294.	0.000304	0.0000	2.1832
29.67	0.1217	40	8.05	1076.9	1068.9	2438.	0.000410	0.0162	2.1394
29.56	0.1780	50	18.08	1081.4	1063.3	1702.	0.000587	0.0361	2.0865
29.40	0.2562	60	28.08	1085.9	1057.8	1208.	0.000828	0.0555	2.0358
29.18	0.3626	70	38.06	1090.3	1052.3	871.	0.001148	0.0745	1.9868
28.89	0.505	80	48.03	1094.8	1046.7	636.8	0.001570	0.0932	1.9398
28.50	0.696	90	58.00	1099.2	1041.2	469.3	0.002131	0.1114	1.8944
28.00	0.946	100	67.97	1103.6	1035.6	350.8	0.002851	0.1295	1.8505
27.88	1	101.83	69.8	1104.4	1034.6	333.0	0.00300	0.1327	1.8427
25.85	2	126.15	94.0	1115.0	1021.0	173.5	0.00576	0.1749	1.7431
23.81	3	141.52	109.4	1121.6	1012.3	118.5	0.00845	0.2008	1.6840
21.78	4	153.01	120.9	1126.5	1005.7	90.5	0.01107	0.2198	1.6416
19.74	5	162.28	130.1	1130.5	1000.3	73.33	0.01364	0.2348	1.6084
17.70	6	170.06	137.9	1133.7	995.8	61.89	0.01616	0.2471	1.5814
15.67	7	176.85	144.7	1136.5	991.8	53.56	0.01867	0.2579	1.5582
13.63	8	182.86	150.8	1139.0	988.2	47.27	0.02115	0.2673	1.5380
11.60	9	188.27	156.2	1141.1	985.0	42.36	0.02361	0.2756	1.5202
9.56	10	193.22	161.1	1143.1	982.0	38.38	0.02606	0.2832	1.5042
7.52	11	197.75	165.7	1144.9	979.2	35.10	0.02849	0.2902	1.4895
5.49	12	201.96	169.9	1146.5	976.6	32.36	0.03090	0.2967	1.4760
3.45	13	205.87	173.8	1148.0	974.2	30.03	0.03330	0.3025	1.4639
1.42	14	209.55	177.5	1149.4	971.9	28.02	0.03569	0.3081	1.4523
Lbs. gage	14.70	212.0	180.0	1150.4	970.4	26.79	0.03732	0.3118	1.4447
0.3	15	213.0	181.0	1150.7	969.7	26.27	0.03806	0.3133	1.4416
1.3	16	216.3	184.4	1152.0	967.6	24.79	0.04042	0.3183	1.4311
2.3	17	219.4	187.5	1153.1	965.6	23.38	0.04277	0.3229	1.4215
3.3	18	222.4	190.5	1154.2	963.7	22.16	0.04512	0.3273	1.4127
4.3	19	225.2	193.4	1155.2	961.8	21.07	0.04746	0.3315	1.4045
5.3	20	228.0	196.1	1156.2	960.0	20.08	0.04980	0.3355	1.3965
6.3	21	230.6	198.8	1157.1	958.3	19.18	0.05213	0.3393	1.3887
7.3	22	233.1	201.3	1158.0	956.7	18.37	0.05445	0.3430	1.3811
8.3	23	235.5	203.8	1158.8	955.1	17.62	0.05676	0.3465	1.3739
9.3	24	237.8	206.1	1159.6	953.5	16.93	0.05907	0.3499	1.3670
10.3	25	240.1	208.4	1160.4	952.0	16.30	0.0614	0.3532	1.3604
11.3	26	242.2	210.6	1161.2	950.6	15.72	0.0636	0.3564	1.3542
12.3	27	244.4	212.7	1161.9	949.2	15.18	0.0659	0.3594	1.3483
13.3	28	246.4	214.8	1162.6	947.8	14.67	0.0682	0.3623	1.3425
14.3	29	248.4	216.8	1163.2	946.4	14.19	0.0705	0.3652	1.3367
15.3	30	250.3	218.8	1163.9	945.1	13.74	0.0728	0.3680	1.3311
16.3	31	252.2	220.7	1164.5	943.8	13.32	0.0751	0.3707	1.3257

Properties of Saturated Steam (Continued)

(Condensed by Kent from Marks and Davis's Steam Tables.)

Gage pressure, pounds per square inch	Absolute pressure, pounds per square inch	Temperature, Fahrenheit	Total heat above 32° F. In the water h, heat-units	Total heat above 32° F. In the steam H, heat-units	Latent heat $L=H-h$, heat-units	Volume, cubic feet in 1 pound of steam	Weight of 1 cubic foot steam, pound	Entropy of the water	Entropy of evaporation
17.3	32	254.1	222.6	1165.1	942.5	12.93	0.0773	0.3733	1.3205
18.3	33	255.8	224.4	1165.7	941.3	12.57	0.0795	0.3759	1.3155
19.3	34	257.6	226.2	1166.3	940.1	12.22	0.0818	0.3784	1.3107
20.3	35	259.3	227.9	1166.8	938.9	11.89	0.0841	0.3808	1.3060
21.3	36	261.0	229.6	1167.3	937.7	11.58	0.0863	0.3832	1.3014
22.3	37	262.6	231.3	1167.8	936.6	11.29	0.0886	0.3855	1.2969
23.3	38	264.2	232.9	1168.4	935.5	11.01	0.0908	0.3877	1.2925
24.3	39	265.8	234.5	1168.9	934.4	10.74	0.0931	0.3899	1.2882
25.3	40	267.3	236.1	1169.4	933.3	10.49	0.0953	0.3920	1.2841
26.3	41	268.7	237.6	1169.8	932.2	10.25	0.0976	0.3941	1.2800
27.3	42	270.2	239.1	1170.3	931.2	10.02	0.0998	0.3962	1.2759
28.3	43	271.7	240.5	1170.7	930.2	9.80	0.1020	0.3982	1.2720
29.3	44	273.1	242.0	1171.2	929.2	9.59	0.1043	0.4002	1.2681
30.3	45	274.5	243.4	1171.6	928.2	9.39	0.1065	0.4021	1.2644
31.3	46	275.8	244.8	1172.0	927.2	9.20	0.1087	0.4040	1.2607
32.3	47	277.2	246.1	1172.4	926.3	9.02	0.1109	0.4059	1.2571
33.3	48	278.5	247.5	1172.8	925.3	8.84	0.1131	0.4077	1.2536
34.3	49	279.8	248.8	1173.2	924.4	8.67	0.1153	0.4095	1.2502
35.3	50	281.0	250.1	1173.6	923.5	8.51	0.1175	0.4113	1.2468
36.3	51	282.3	251.4	1174.0	922.6	8.35	0.1197	0.4130	1.2435
37.3	52	283.5	252.6	1174.3	921.7	8.20	0.1219	0.4147	1.2402
38.3	53	284.7	253.9	1174.7	920.8	8.05	0.1241	0.4164	1.2370
39.3	54	285.9	255.1	1175.0	919.9	7.91	0.1263	0.4180	1.2339
40.3	55	287.1	256.3	1175.4	919.0	7.78	0.1285	0.4196	1.2309
41.3	56	288.2	257.5	1175.7	918.2	7.65	0.1307	0.4212	1.2278
42.3	57	289.4	258.7	1176.0	917.4	7.52	0.1329	0.4227	1.2248
43.3	58	290.5	259.8	1176.4	916.5	7.40	0.1350	0.4242	1.2218
44.3	59	291.6	261.0	1176.7	915.7	7.28	0.1372	0.4257	1.2189
45.3	60	292.7	262.1	1177.0	914.9	7.17	0.1394	0.4272	1.2160
46.3	61	293.8	263.2	1177.3	914.1	7.06	0.1416	0.4287	1.2132
47.3	62	294.9	264.3	1177.6	913.3	6.95	0.1438	0.4302	1.2104
48.3	63	295.9	265.4	1177.9	912.5	6.85	0.1460	0.4316	1.2077
49.3	64	297.0	266.4	1178.2	911.8	6.75	0.1482	0.4330	1.2050
50.3	65	298.0	267.5	1178.5	911.0	6.65	0.1503	0.4344	1.2024
51.3	66	299.0	268.5	1178.8	910.2	6.56	0.1525	0.4358	1.1998
52.3	67	300.0	269.6	1179.0	909.5	6.47	0.1547	0.4371	1.1972
53.3	68	301.0	270.6	1179.3	908.7	6.38	0.1569	0.4385	1.1946
54.3	69	302.0	271.6	1179.6	908.0	6.29	0.1590	0.4398	1.1921
55.3	70	302.9	272.6	1179.8	907.2	6.20	0.1612	0.4411	1.1896
56.3	71	303.9	273.6	1180.1	906.5	6.12	0.1634	0.4424	1.1872

Properties of Saturated Steam (Continued)

(Condensed by Kent from Marks and Davis's Steam Tables.)

Gage pressure, pounds per square inch	Absolute pressure, pounds per square inch	Temperature, Fahrenheit	Total heat above 32° F. In the water h, heat-units	Total heat above 32° F. In the steam H, heat-units	Latent heat $L=H-h$, heat-units	Volume, cubic feet in 1 pound of steam	Weight of 1 cubic foot steam, pound	Entropy of the water	Entropy of evaporation
57.3	72	304.8	274.5	1180.4	905.8	6.04	0.1656	0.4437	1.1848
58.3	73	305.8	275.5	1180.6	905.1	5.96	0.1678	0.4449	1.1825
59.3	74	306.7	276.5	1180.9	904.4	5.89	0.1699	0.4462	1.1801
60.3	75	307.6	277.4	1181.1	903.7	5.81	0.1721	0.4474	1.1778
61.3	76	308.5	278.3	1181.4	903.0	5.74	0.1743	0.4487	1.1755
62.3	77	309.4	279.3	1181.6	902.3	5.67	0.1764	0.4499	1.1732
63.3	78	310.3	280.2	1181.8	901.7	5.60	0.1786	0.4511	1.1710
64.3	79	311.2	281.1	1182.1	901.0	5.54	0.1808	0.4523	1.1687
65.3	80	312.0	282.0	1182.3	900.3	5.47	0.1829	0.4535	1.1665
66.3	81	312.9	282.9	1182.5	899.7	5.41	0.1851	0.4546	1.1644
67.3	82	313.8	283.8	1182.8	899.0	5.34	0.1873	0.4557	1.1623
68.3	83	314.6	284.6	1183.0	898.4	5.28	0.1894	0.4568	1.1602
69.3	84	315.4	285.5	1183.2	897.7	5.22	0.1915	0.4579	1.1581
70.3	85	316.3	286.3	1183.4	897.1	5.16	0.1937	0.4590	1.1561
71.3	86	317.1	287.2	1183.6	896.4	5.10	0.1959	0.4601	1.1540
72.3	87	317.9	288.0	1183.8	895.8	5.05	0.1980	0.4612	1.1520
73.3	88	318.7	288.9	1184.0	895.2	5.00	0.2001	0.4623	1.1500
74.3	89	319.5	289.7	1184.2	894.6	4.94	0.2023	0.4633	1.1481
75.3	90	320.3	290.5	1184.4	893.9	4.89	0.2044	0.4644	1.1461
76.3	91	321.1	291.3	1184.6	893.3	4.84	0.2065	0.4654	1.1442
77.3	92	321.8	292.1	1184.8	892.7	4.79	0.2087	0.4664	1.1423
78.3	93	322.6	292.9	1185.0	892.1	4.74	0.2109	0.4674	1.1404
79.3	94	323.4	293.7	1185.2	891.5	4.69	0.2130	0.4684	1.1385
80.3	95	324.1	294.5	1185.4	890.9	4.65	0.2151	0.4694	1.1367
81.3	96	324.9	295.3	1185.6	890.3	4.60	0.2172	0.4704	1.1348
82.3	97	325.6	296.1	1185.8	889.7	4.56	0.2193	0.4714	1.1330
83.3	98	326.4	296.8	1186.0	889.2	4.51	0.2215	0.4724	1.1312
84.3	99	327.1	297.6	1186.2	888.6	4.47	0.2237	0.4733	1.1295
85.3	100	327.8	298.3	1186.3	888.0	4.429	0.2258	0.4743	1.1277
87.3	102	329.3	299.8	1186.7	886.9	4.347	0.2300	0.4762	1.1242
89.3	104	330.7	301.3	1187.0	885.8	4.268	0.2343	0.4780	1.1208
91.3	106	332.0	302.7	1187.4	884.7	4.192	0.2336	0.4798	1.1174
93.3	108	333.4	304.1	1187.7	883.6	4.118	0.2429	0.4816	1.1141
95.3	110	334.8	305.5	1188.0	882.5	4.047	0.2472	0.4834	1.1108
97.3	112	336.1	306.9	1188.4	881.4	3.978	0.2514	0.4852	1.1076
99.3	114	337.4	308.3	1188.7	880.4	3.912	0.2556	0.4869	1.1045
101.3	116	338.7	309.6	1189.0	879.3	3.848	0.2599	0.4886	1.1014
103.3	118	340.0	311.0	1189.3	878.3	3.786	0.2641	0.4903	1.0984
105.3	120	341.3	312.3	1189.6	877.2	3.726	0.2683	0.4919	1.0954
107.3	122	342.5	313.6	1189.8	876.2	3.668	0.2726	0.4935	1.0924

Properties of Saturated Steam (Continued)

(Condensed by Kent from Marks and Davis's Steam Tables.)

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109.3	124	343.8	314.9	1190.1	875.2	3.611	0.2769	0.4951	1.0895
111.3	126	345.0	316.2	1190.4	874.2	3.556	0.2812	0.4967	1.0865
113.3	128	346.2	317.4	1190.7	873.3	3.504	0.2854	0.4982	1.0837
115.3	130	347.4	318.6	1191.0	872.3	3.452	0.2897	0.4998	1.0809
117.3	132	348.5	319.9	1191.2	871.3	3.402	0.2939	0.5013	1.0782
119.3	134	349.7	321.1	1191.5	870.4	3.354	0.2981	0.5028	1.0755
121.3	136	350.8	322.3	1191.7	869.4	3.308	0.3023	0.5043	1.0728
123.3	138	352.0	323.4	1192.0	868.5	3.263	0.3065	0.5057	1.0702
125.3	140	353.1	324.6	1192.2	867.6	3.219	0.3107	0.5072	1.0675
127.3	142	354.2	325.8	1192.5	866.7	3.175	0.3150	0.5086	1.0649
129.3	144	355.3	326.9	1192.7	865.8	3.133	0.3192	0.5100	1.0624
131.3	146	356.3	328.0	1192.9	864.9	3.092	0.3234	0.5114	1.0599
133.3	148	357.4	329.1	1193.2	864.0	3.052	0.3276	0.5128	1.0574
135.3	150	358.5	330.2	1193.4	863.2	3.012	0.3320	0.5142	1.0550
137.3	152	359.5	331.4	1193.6	862.3	2.974	0.3362	0.5155	1.0525
139.3	154	360.5	332.4	1193.8	861.4	2.938	0.3404	0.5169	1.0501
141.3	156	361.6	333.5	1194.1	860.6	2.902	0.3446	0.5182	1.0477
143.3	158	362.6	334.6	1194.3	859.7	2.868	0.3488	0.5195	1.0454
145.3	160	363.6	335.6	1194.5	858.8	2.834	0.3529	0.5208	1.0431
147.3	162	364.6	336.7	1194.7	858.0	2.801	0.3570	0.5220	1.0409
149.3	164	365.6	337.7	1194.9	857.2	2.769	0.3612	0.5233	1.0387
151.3	166	366.5	338.7	1195.1	856.4	2.737	0.3654	0.5245	1.0365
153.3	168	367.5	339.7	1195.3	855.5	2.706	0.3696	0.5257	1.0343
155.3	170	368.5	340.7	1195.4	854.7	2.675	0.3738	0.5269	1.0321
157.3	172	369.4	341.7	1195.6	853.9	2.645	0.3780	0.5281	1.0300
159.3	174	370.4	342.7	1195.8	853.1	2.616	0.3822	0.5293	1.0278
161.3	176	371.3	343.7	1196.0	852.3	2.588	0.3864	0.5305	1.0257
163.3	178	372.2	344.7	1196.2	851.5	2.560	0.3906	0.5317	1.0235
165.3	180	373.1	345.6	1196.4	850.8	2.533	0.3948	0.5328	1.0215
167.3	182	374.0	346.6	1196.6	850.0	2.507	0.3989	0.5339	1.0195
169.3	184	374.9	347.6	1196.8	849.2	2.481	0.4031	0.5351	1.0174
171.3	186	375.8	348.5	1196.9	848.4	2.455	0.4073	0.5362	1.0154
173.3	188	376.7	349.4	1197.1	847.7	2.430	0.4115	0.5373	1.0134
175.3	190	377.6	350.4	1197.3	846.9	2.406	0.4157	0.5384	1.0114
177.3	192	378.5	351.3	1197.4	846.1	2.381	0.4199	0.5395	1.0095
179.3	194	379.3	352.2	1197.6	845.4	2.358	0.4241	0.5405	1.0076
181.3	196	380.2	353.1	1197.8	844.7	2.335	0.4283	0.5416	1.0056
183.3	198	381.0	354.0	1197.9	843.9	2.312	0.4325	0.5426	1.0038
185.3	200	381.9	354.9	1198.1	843.2	2.290	0.437	0.5437	1.0019
190.3	205	384.0	357.1	1198.5	841.4	2.237	0.447	0.5463	0.9973

Properties of Saturated Steam (Concluded)

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195.3	210	386.0	359.2	1198.8	839.6	2.187	0.457	0.5488	0.9928
200.3	215	388.0	361.4	1199.2	837.9	2.138	0.468	0.5513	0.9885
205.3	220	389.9	363.4	1199.6	836.2	2.091	0.478	0.5538	0.9841
210.3	225	391.9	365.5	1199.9	834.4	2.046	0.489	0.5562	0.9799
215.3	230	393.8	367.5	1200.2	832.8	2.004	0.499	0.5586	0.9758
220.3	235	395.6	369.4	1200.6	831.1	1.964	0.509	0.5610	0.9717
225.3	240	397.4	371.4	1200.9	829.5	1.924	0.520	0.5633	0.9676
230.3	245	399.3	373.3	1201.2	827.9	1.887	0.530	0.5655	0.9638
235.3	250	401.1	375.2	1201.5	826.3	1.850	0.541	0.5676	0.9600
245.3	260	404.5	378.9	1202.1	823.1	1.782	0.561	0.5719	0.9525
255.3	270	407.9	382.5	1202.6	820.1	1.718	0.582	0.5760	0.9454
265.3	280	411.2	386.0	1203.1	817.1	1.658	0.603	0.5800	0.9385
275.3	290	414.4	389.4	1203.6	814.2	1.602	0.624	0.5840	0.9316
285.3	300	417.5	392.7	1204.1	811.3	1.551	0.645	0.5878	0.9251
295.3	310	420.5	395.9	1204.5	808.5	1.502	0.666	0.5915	0.9187
305.3	320	423.4	399.1	1204.9	805.8	1.456	0.687	0.5951	0.9125
315.3	330	426.3	402.2	1205.3	803.1	1.413	0.708	0.5986	0.9065
325.3	340	429.1	405.3	1205.7	800.4	1.372	0.729	0.6020	0.9006
335.3	350	431.9	408.2	1206.1	797.8	1.334	0.750	0.6053	0.8949
345.3	360	434.6	411.2	1206.4	795.3	1.298	0.770	0.6085	0.8894
355.3	370	437.2	414.0	1206.8	792.8	1.264	0.791	0.6116	0.8840
365.3	380	439.8	416.8	1207.1	790.3	1.231	0.812	0.6147	0.8788
375.3	390	442.3	419.5	1207.4	787.9	1.200	0.833	0.6178	0.8737
385.3	400	444.8	422.	1208.	786.	1.17	0.86	0.621	0.868
435.3	450	456.5	435.	1209.	774.	1.04	0.96	0.635	0.844
485.3	500	467.3	448.	1210.	762.	0.93	1.08	0.648	0.822
535.3	550	477.3	459.	1210.	751.	0.83	1.20	0.659	0.801
585.3	600	486.6	469.	1210.	741.	0.76	1.32	0.670	0.783

Factors of Evaporation

The factors in the following table, which has been condensed from Kent's Mechanical Engineers' Pocket Book, were obtained, for the various feed-water temperatures and steam pressures given, by subtracting the heat above 32° in one pound of feed-water from the total heat above 32° in one pound of steam, and dividing the remainder by 970.4, the latent heat of steam at 212°. The values of the total heat of steam, heat of feed-water and latent heat of steam are those given in Marks and Davis's steam tables. Intermediate values may be found by interpolation.

Example: Given the boiler pressure = 115 pounds per square inch absolute, and the temperature of feed-water = 62° F., to find the factor of evaporation. Look in the column headed 115 and opposite 62°; the factor required is 1.1941. It will therefore require 1.1941 times as many heat-units to evaporate a certain weight of water from a feed-water temperature of 62° F. into steam under 115 pounds pressure, as would be required to evaporate the same weight of water from a temperature of 212° F. into steam at 212° F., that is, from and at 212° F.

Factors of Evaporation

Gage pressure, pounds	0.3	10.3	20.3	30.3	40.3	50.3	60.3	70.3	80.3
Absolute pressure, pounds	15.	25.	35.	45.	55.	65.	75.	85.	95.
Temperature of feed-water, ° F.	Factors of evaporation								
32	1.1858	1.1958	1.2024	1.2073	1.2113	1.2144	1.2171	1.2195	1.2216
38	1.1796	1.1896	1.1962	1.2011	1.2050	1.2082	1.2109	1.2133	1.2153
44	1.1734	1.1834	1.1900	1.1949	1.1988	1.2020	1.2047	1.2071	1.2091
50	1.1672	1.1772	1.1838	1.1887	1.1926	1.1958	1.1985	1.2009	1.2029
56	1.1610	1.1710	1.1776	1.1825	1.1864	1.1896	1.1923	1.1947	1.1967
62	1.1548	1.1648	1.1714	1.1763	1.1803	1.1835	1.1861	1.1885	1.1906
68	1.1486	1.1586	1.1652	1.1702	1.1741	1.1773	1.1800	1.1823	1.1844
74	1.1425	1.1525	1.1591	1.1640	1.1679	1.1711	1.1738	1.1762	1.1782
80	1.1363	1.1463	1.1529	1.1578	1.1618	1.1650	1.1676	1.1700	1.1721
86	1.1301	1.1401	1.1467	1.1518	1.1556	1.1588	1.1615	1.1638	1.1659
92	1.1240	1.1340	1.1406	1.1455	1.1494	1.1526	1.1553	1.1577	1.1597
98	1.1178	1.1278	1.1344	1.1393	1.1433	1.1465	1.1491	1.1515	1.1536
104	1.1116	1.1216	1.1282	1.1332	1.1371	1.1403	1.1430	1.1453	1.1474
110	1.1055	1.1155	1.1221	1.1270	1.1309	1.1341	1.1368	1.1392	1.1412
116	1.0993	1.1093	1.1159	1.1209	1.1248	1.1280	1.1306	1.1330	1.1351
122	1.0931	1.1031	1.1097	1.1147	1.1186	1.1218	1.1245	1.1269	1.1289
128	1.0870	1.0970	1.1036	1.1085	1.1124	1.1156	1.1183	1.1207	1.1227
134	1.0808	1.0908	1.0974	1.1023	1.1063	1.1095	1.1121	1.1145	1.1166
140	1.0746	1.0846	1.0912	1.0962	1.1001	1.1033	1.1060	1.1083	1.1104
146	1.0685	1.0785	1.0851	1.0900	1.0939	1.0971	1.0998	1.1022	1.1042
152	1.0623	1.0723	1.0789	1.0838	1.0877	1.0909	1.0936	1.0960	1.0980
158	1.0561	1.0661	1.0727	1.0776	1.0816	1.0847	1.0874	1.0898	1.0919
164	1.0499	1.0599	1.0665	1.0715	1.0754	1.0786	1.0812	1.0836	1.0857
170	1.0437	1.0537	1.0603	1.0653	1.0692	1.0724	1.0751	1.0774	1.0795
176	1.0375	1.0475	1.0541	1.0591	1.0630	1.0662	1.0689	1.0712	1.0733
182	1.0313	1.0413	1.0479	1.0529	1.0568	1.0600	1.0627	1.0650	1.0671
188	1.0251	1.0351	1.0417	1.0467	1.0506	1.0538	1.0565	1.0588	1.0609
194	1.0189	1.0289	1.0355	1.0405	1.0444	1.0476	1.0503	1.0526	1.0547
200	1.0127	1.0227	1.0293	1.0343	1.0382	1.0414	1.0441	1.0464	1.0485
206	1.0065	1.0165	1.0231	1.0281	1.0320	1.0352	1.0379	1.0402	1.0423
212	1.0003	1.0103	1.0169	1.0218	1.0258	1.0290	1.0316	1.0340	1.0361

Factors of Evaporation (Continued)

Gage pressure, pounds	90.3	100.3	110.3	120.3	130.3	140.3	150.3	160.3	170.3
Absolute pressure, pounds	105.	115.	125.	135.	145.	155.	165.	175.	185.
Temperature of feed-water, ° F.	Factors of evaporation								
32	1.2234	1.2251	1.2266	1.2279	1.2292	1.2304	1.2315	1.2324	1.2333
38	1.2172	1.2188	1.2204	1.2217	1.2230	1.2242	1.2252	1.2262	1.2271
44	1.2110	1.2126	1.2142	1.2155	1.2168	1.2180	1.2190	1.2200	1.2209
50	1.2048	1.2064	1.2080	1.2093	1.2106	1.2118	1.2128	1.2137	1.2147
56	1.1986	1.2002	1.2018	1.2031	1.2044	1.2056	1.2066	1.2076	1.2085
62	1.1924	1.1941	1.1956	1.1970	1.1982	1.1994	1.2005	1.2014	1.2023
68	1.1862	1.1879	1.1894	1.1908	1.1920	1.1933	1.1943	1.1952	1.1961
74	1.1801	1.1817	1.1833	1.1846	1.1859	1.1871	1.1881	1.1890	1.1900
80	1.1739	1.1756	1.1771	1.1785	1.1797	1.1809	1.1820	1.1829	1.1838
86	1.1678	1.1694	1.1710	1.1723	1.1735	1.1748	1.1758	1.1767	1.1776
92	1.1616	1.1632	1.1648	1.1661	1.1674	1.1686	1.1696	1.1705	1.1715
98	1.1554	1.1571	1.1586	1.1600	1.1612	1.1624	1.1635	1.1644	1.1653
104	1.1492	1.1509	1.1525	1.1538	1.1550	1.1563	1.1573	1.1582	1.1592
110	1.1431	1.1447	1.1463	1.1476	1.1489	1.1501	1.1511	1.1521	1.1530
116	1.1369	1.1386	1.1401	1.1415	1.1427	1.1439	1.1450	1.1459	1.1468
122	1.1308	1.1324	1.1340	1.1353	1.1365	1.1378	1.1388	1.1397	1.1407
128	1.1246	1.1262	1.1278	1.1291	1.1304	1.1316	1.1326	1.1336	1.1345
134	1.1184	1.1201	1.1216	1.1230	1.1242	1.1254	1.1265	1.1274	1.1283
140	1.1123	1.1139	1.1154	1.1168	1.1180	1.1193	1.1203	1.1212	1.1221
146	1.1061	1.1077	1.1093	1.1106	1.1119	1.1131	1.1141	1.1150	1.1160
152	1.0999	1.1015	1.1031	1.1044	1.1057	1.1069	1.1079	1.1089	1.1098
158	1.0937	1.0954	1.0969	1.0982	1.0995	1.1007	1.1018	1.1027	1.1036
164	1.0875	1.0892	1.0907	1.0921	1.0933	1.0945	1.0956	1.0965	1.0974
170	1.0813	1.0830	1.0845	1.0859	1.0871	1.0883	1.0894	1.0903	1.0912
176	1.0752	1.0768	1.0783	1.0797	1.0809	1.0822	1.0832	1.0841	1.0850
182	1.0690	1.0706	1.0721	1.0735	1.0747	1.0760	1.0770	1.0779	1.0788
188	1.0628	1.0644	1.0660	1.0673	1.0685	1.0698	1.0708	1.0717	1.0727
194	1.0566	1.0582	1.0597	1.0611	1.0623	1.0636	1.0646	1.0655	1.0664
200	1.0504	1.0520	1.0535	1.0549	1.0561	1.0574	1.0584	1.0593	1.0602
206	1.0441	1.0458	1.0473	1.0487	1.0499	1.0511	1.0522	1.0531	1.0540
212	1.0379	1.0396	1.0411	1.0425	1.0437	1.0449	1.0460	1.0469	1.0478

Factors of Evaporation (Concluded)

Gage pressure, pounds	180.3	190.3	200.3	210.3	220.3	230.3	240.3	250.3
Absolute pressure, pounds	195.	205.	215.	225.	235.	245.	255.	265.
Temperature of feed-water, ° F.	Factors of evaporation							
32	1.2342	1.2351	1.2358	1.2365	1.2372	1.2378	1.2384	1.2390
38	1.2280	1.2288	1.2296	1.2303	1.2310	1.2316	1.2322	1.2328
44	1.2218	1.2226	1.2234	1.2241	1.2248	1.2254	1.2260	1.2266
50	1.2156	1.2164	1.2171	1.2179	1.2186	1.2192	1.2198	1.2204
56	1.2094	1.2102	1.2110	1.2117	1.2124	1.2130	1.2136	1.2142
62	1.2032	1.2041	1.2048	1.2055	1.2062	1.2068	1.2074	1.2080
68	1.1971	1.1979	1.1986	1.1993	1.2001	1.2007	1.2012	1.2019
74	1.1909	1.1917	1.1924	1.1932	1.1939	1.1945	1.1951	1.1957
80	1.1847	1.1856	1.1863	1.1870	1.1877	1.1883	1.1889	1.1895
86	1.1786	1.1794	1.1801	1.1808	1.1816	1.1822	1.1827	1.1834
92	1.1724	1.1732	1.1739	1.1747	1.1754	1.1760	1.1766	1.1772
98	1.1662	1.1671	1.1678	1.1685	1.1692	1.1698	1.1704	1.1710
104	1.1601	1.1609	1.1616	1.1624	1.1631	1.1637	1.1643	1.1649
110	1.1539	1.1547	1.1555	1.1562	1.1569	1.1575	1.1581	1.1587
116	1.1478	1.1486	1.1493	1.1500	1.1507	1.1514	1.1519	1.1525
122	1.1416	1.1424	1.1431	1.1439	1.1446	1.1452	1.1458	1.1464
128	1.1354	1.1362	1.1370	1.1377	1.1384	1.1390	1.1396	1.1402
134	1.1292	1.1301	1.1308	1.1315	1.1322	1.1329	1.1334	1.1340
140	1.1231	1.1239	1.1246	1.1253	1.1261	1.1267	1.1272	1.1279
146	1.1169	1.1177	1.1184	1.1192	1.1199	1.1205	1.1211	1.1217
152	1.1107	1.1115	1.1123	1.1130	1.1137	1.1143	1.1149	1.1155
158	1.1045	1.1054	1.1061	1.1068	1.1075	1.1081	1.1087	1.1093
164	1.0984	1.0992	1.0999	1.1006	1.1013	1.1019	1.1025	1.1031
170	1.0922	1.0930	1.0937	1.0944	1.0951	1.0958	1.0963	1.0969
176	1.0860	1.0868	1.0875	1.0882	1.0890	1.0896	1.0901	1.0908
182	1.0798	1.0806	1.0813	1.0820	1.0828	1.0834	1.0839	1.0846
188	1.0736	1.0744	1.0751	1.0758	1.0766	1.0772	1.0778	1.0784
194	1.0674	1.0682	1.0689	1.0696	1.0704	1.0710	1.0715	1.0722
200	1.0612	1.0620	1.0627	1.0634	1.0642	1.0648	1.0653	1.0660
206	1.0550	1.0558	1.0565	1.0572	1.0579	1.0586	1.0591	1.0597
212	1.0487	1.0496	1.0503	1.0510	1.0517	1.0523	1.0529	1.0535

SUPERHEATED STEAM

Steam in the presence of the water from which it is generated is called "saturated steam"; it has the same temperature as the water, and can have only one pressure and one density at any given temperature — the three are in fixed relationship to each other. Superheated steam has a higher temperature than saturated steam at the same pressure, and is produced by adding heat to saturated steam in a separate vessel called a superheater. It is independent of pressure, since at any pressure the steam may have any desired temperature. In practice the superheater is an extension of the steam space of the boiler, with which it is in open communication, and the pressure of the steam in the superheater is practically the boiler pressure.

Volume of Superheated Steam. Superheated steam is greater in volume than saturated steam of the same pressure. Linde's equation (1905) is

$$pv = 0.5962\,T - p(1 + 0.0014\,p)\left(\frac{150\,300\,000}{T^3} - 0.0833\right),$$

where p = pressure in pounds per square inch;
v = volume in cubic feet;
T = absolute temperature.

Specific Heat of Superheated Steam. The following table of Knoblauch and Jakob (from Peabody's Steam Tables) gives the mean specific heat of superheated steam from the temperature of saturation to various temperatures at several pressures:

Kilograms per square centimeter		1	2	4	6	8	10	12	14	16	18	20
Pounds per square inch		14.2	28.4	56.9	85.3	113.8	142.2	170.6	199.1	227.5	256.0	284.4
Temperature saturation °C.		99	120	143	158	169	179	187	194	200	206	211
Temperature saturation °F.		210	248	289	316	336	354	369	381	392	403	412
°F.	°C.											
212	100	0.463										
302	150	.462	.478	.515								
392	200	.462	.475	.502	.530	.560	.597	.635	.677			
482	250	.463	.474	.495	.514	.532	.552	.570	.588	.609	.635	.664
572	300	.464	.475	.492	.505	.517	.530	.541	.550	.561	.572	.585
662	350	.468	.477	.492	.503	.512	.522	.529	.536	.543	.550	.557
752	400	.473	.481	.494	.504	.512	.520	.526	.531	.537	.542	.547

Thus the mean specific heat of steam at 142.2 pounds pressure when superheated to 572° F. is 0.53. The heat required to raise 1 pound of steam from a saturation temperature of 354° to 572° is $(572-354)$ $0.53 = 115.5$ B.T.U. The total heat of the superheated steam is the sum of this quantity and the heat in the saturated steam. It is given directly in the properties of superheated steam for various degrees of superheat, pages 339 and 340.

Advantages of Superheating. The advantage to be gained by superheating is not due to increased thermodynamic efficiency. The economy which results from the application of superheat is due to the reduction of the internal thermal waste of the engine, incident to cylinder condensation. The steam entering the cylinder strikes the walls, which have been cooled by the previous exhaust. The heat necessary to warm the walls to the temperature of the entering steam can be supplied only by the steam, and if it is saturated some of it must be condensed. If the steam is superheated it must be reduced to the temperature of saturated steam at the given pressure, before condensation takes place.

Superheating is superior to any other known means of reduction of this internal waste. The saving due to its use is found to be greater with engines that are most inefficient with saturated steam; small engines profit more by it than large, slow engines more than fast, and single engines more than multiple expansion engines.

Properties of Superheated Steam

(Condensed by Kent from Marks and Davis's Steam Tables.)

V = specific volume in cubic feet per pound; H = total heat, from water at 32° F. in B.T.U. per pound; N = entropy, from water at 32°.

Pressure absolute, lbs. per sq. inch	Temperature saturated steam		Degrees of superheat				
			0	20	50	100	150
20	228.0	V	20.08	20.73	21.69	23.25	24.80
		H	1156.2	1165.7	1179.9	1203.5	1227.1
		N	1.7320	1.7456	1.7652	1.7961	1.8251
40	267.3	V	10.49	10.83	11.33	12.13	12.93
		H	1169.4	1179.3	1194.0	1218.4	1242.4
		N	1.6761	1.6895	1.7089	1.7392	1.7674
60	292.7	V	7.17	7.40	7.75	8.30	8.84
		H	1177.0	1187.3	1202.6	1227.6	1252.1
		N	1.6432	1.6568	1.6761	1.7062	1.7342
80	312.0	V	5.47	5.65	5.92	6.34	6.75
		H	1182.3	1193.0	1208.8	1234.3	1259.0
		N	1.6200	1.6338	1.6532	1.6833	1.7110
100	327.8	V	4.43	4.58	4.79	5.14	5.47
		H	1186.3	1197.5	1213.8	1239.7	1264.7
		N	1.6020	1.6160	1.6358	1.6658	1.6933
120	341.3	V	3.73	3.85	4.04	4.33	4.62
		H	1189.6	1201.1	1217.9	1244.1	1269.3
		N	1.5873	1.6016	1.6216	1.6517	1.6789
140	353.1	V	3.22	3.32	3.49	3.75	4.00
		H	1192.2	1204.3	1221.4	1248.0	1273.3
		N	1.5747	1.5894	1.6096	1.6395	1.6666
160	363.6	V	2.83	2.93	3.07	3.30	3.53
		H	1194.5	1207.0	1224.5	1251.3	1276.8
		N	1.5639	1.5789	1.5993	1.6292	1.6561
180	373.1	V	2.53	2.62	2.75	2.96	3.16
		H	1196.4	1209.4	1227.2	1254.3	1279.9
		N	1.5543	1.5697	1.5904	1.6201	1.6468
200	381.9	V	2.29	2.37	2.49	2.68	2.86
		H	1198.1	1211.6	1229.8	1257.1	1282.6
		N	1.5456	1.5614	1.5823	1.6120	1.6385
220	389.9	V	2.09	2.16	2.28	2.45	2.62
		H	1199.6	1213.6	1232.2	1259.6	1285.2
		N	1.5379	1.5541	1.5753	1.6049	1.6312
240	397.4	V	1.92	1.99	2.09	2.26	2.42
		H	1200.9	1215.4	1234.3	1261.9	1287.6
		N	1.5309	1.5476	1.5690	1.5985	1.6246
260	404.5	V	1.78	1.84	1.94	2.10	2.24
		H	1202.1	1217.1	1236.4	1264.1	1289.9
		N	1.5244	1.5416	1.5631	1.5926	1.6186
280	411.2	V	1.66	1.72	1.81	1.95	2.09
		H	1203.1	1218.7	1238.4	1266.2	1291.9
		N	1.5185	1.5362	1.5580	1.5873	1.6133
300	417.5	V	1.55	1.60	1.69	1.83	1.96
		H	1204.1	1220.2	1240.3	1268.2	1294.0
		N	1.5129	1.5310	1.5530	1.5824	1.6082
400	444.8	V	1.17	1.21	1.28	1.40	1.50
		H	1207.7	1227.2	1248.6	1276.9	1303.0
		N	1.4894	1.5107	1.5336	1.5625	1.5880
500	467.3	V	0.93	0.97	1.03	1.13	1.22
		H	1210	1233	1256	1285	1311
		N	1.470	1.496	1.519	1.548	1.573

Properties of Superheated Steam (Concluded)

(Condensed by Kent from Marks and Davis's Steam Tables.)

V = specific volume in cubic feet per pound; H = total heat, from water at 32° F. in B.T.U. per pound; N = entropy, from water at 32°.

Pressure absolute, lbs. per sq. inch	Temperature saturated steam		Degrees of superheat				
			200	250	300	400	500
20	228.0	V	26.33	27.85	29.37	32.39	35.40
		H	1250.6	1274.1	1297.6	1344.8	1392.2
		N	1.8524	1.8781	1.9026	1.9479	1.9893
40	267.3	V	13.70	14.48	15.25	16.78	18.30
		H	1266.4	1290.3	1314.1	1361.6	1409.3
		N	1.7940	1.8189	1.8427	1.8867	1.9271
60	292.7	V	9.36	9.89	10.41	11.43	12.45
		H	1276.4	1300.4	1324.3	1372.2	1420.0
		N	1.7603	1.7849	1.8081	1.8511	1.8908
80	312.0	V	7.17	7.56	7.95	8.72	9.49
		H	1283.6	1307.8	1331.9	1379.8	1427.9
		N	1.7368	1.7612	1.7840	1.8265	1.8658
100	327.8	V	5.80	6.12	6.44	7.07	7.69
		H	1289.4	1313.6	1337.8	1385.9	1434.1
		N	1.7188	1.7428	1.7656	1.8079	1.8468
120	341.3	V	4.89	5.17	5.44	5.96	6.48
		H	1294.1	1318.4	1342.7	1391.0	1439.4
		N	1.7041	1.7280	1.7505	1.7924	1.8311
140	353.1	V	4.24	4.48	4.71	5.16	5.61
		H	1298.2	1322.6	1346.9	1395.4	1443.8
		N	1.6916	1.7152	1.7376	1.7792	1.8177
160	363.6	V	3.74	3.95	4.15	4.56	4.95
		H	1301.7	1326.2	1350.6	1399.3	1447.9
		N	1.6810	1.7043	1.7266	1.7680	1.8063
180	373.1	V	3.35	3.54	3.72	4.09	4.44
		H	1304.8	1329.5	1353.9	1402.7	1451.4
		N	1.6716	1.6948	1.7169	1.7581	1.7962
200	381.9	V	3.04	3.21	3.38	3.71	4.03
		H	1307.7	1332.4	1357.0	1405.9	1454.7
		N	1.6632	1.6862	1.7082	1.7493	1.7872
220	389.9	V	2.78	2.94	3.10	3.40	3.69
		H	1310.3	1335.1	1359.8	1408.8	1457.7
		N	1.6558	1.6787	1.7005	1.7415	1.7792
240	397.4	V	2.57	2.71	2.85	3.13	3.40
		H	1312.8	1337.6	1362.3	1411.5	1460.5
		N	1.6492	1.6720	1.6937	1.7344	1.7721
260	404.5	V	2.39	2.52	2.65	2.91	3.16
		H	1315.1	1340.0	1364.7	1414.0	1463.2
		N	1.6430	1.6658	1.6874	1.7280	1.7655
280	411.2	V	2.22	2.35	2.48	2.72	2.95
		H	1317.2	1342.2	1367.0	1416.4	1465.7
		N	1.6375	1.6603	1.6818	1.7223	1.7597
300	417.5	V	2.09	2.21	2.33	2.55	2.77
		H	1319.3	1344.3	1369.2	1418.6	1468.0
		N	1.6323	1.6550	1.6765	1.7168	1.7541
400	444.8	V	1.60	1.70	1.79	1.97	2.14
		H	1328.6	1353.9	1379.1	1429.0	1478.9
		N	1.6117	1.6342	1.6554	1.6955	1.7323
500	467.3	V	1.31	1.39	1.47	1.62	1.76
		H	1337	1362	1388	1438	1489
		N	1.597	1.619	1.640	1.679	1.715

FLOW OF STEAM

Flow of Steam from Orifices. The flow of steam of a higher pressure toward a lower pressure increases as the difference of pressure is increased, until the external pressure becomes only 58 per cent of the absolute initial pressure. Any further reduction of the external pressure, even to the extent of a perfect vacuum, neither increases nor diminishes the flow of steam. In flowing through a nozzle of the best form, the steam expands to the external pressure and to the volume corresponding to this pressure, so long as it is not less than 58 per cent of the internal pressure. For an external pressure of 58 per cent or less, the ratio of expansion is 1.624.

The following formula is frequently used to determine the flow of steam through an orifice against a pressure greater than 58 per cent of the discharge:

$$W = 1.9\,AK\sqrt{(P-d)d},$$

where

W = weight discharged in pounds per minute;
A = area of orifice in square inches;
P = absolute initial pressure in pounds per square inch;
d = difference in pressure between the two sides, in pounds per square inch;
K = coefficient = .93 for a short pipe = .63 for a hole in a thin plate.

Flow of Steam into the Atmosphere. When steam of varying initial pressure is discharged into the atmosphere — the atmospheric pressure being not more than 58 per cent of the initial pressure — the velocity of outflow at constant density, that is, supposing the initial density to be maintained, is given by the formula,

$$V = 3.5953\sqrt{h},$$

where V = the velocity of outflow in feet per second, as for steam of the initial density, and h = the height in feet, of a column of steam of the given initial pressure, the weight of which is equal to the pressure on the unit of base.

The lowest initial pressure to which this formula applies, when steam is discharged into the atmosphere, is 25.37 pounds per square inch.

The following table gives the outflow of steam into the atmosphere for various internal pressures. The velocity of steam above 25.37 pounds per square inch absolute pressure, increases very slowly with the pressure, because the density, and the weight to be moved, increase with the pressure. An average of 900 feet per second may, for approximate calculations, be taken for the velocity of outflow as for constant density, that is, taking the volume of the steam at the initial volume.

Outflow of Steam into the Atmosphere

(D. K. Clark.)

Initial pressure, pounds per square inch absolute	External pressure, pounds per square inch absolute	Expansion in nozzle, ratio	Velocity of outflow at constant density, feet per second	Actual velocity of outflow expanded, feet per second	Discharge, pounds per square inch per minute
25.37	14.7	1.624	863	1401	22.81
30	14.7	1.624	867	1408	26.84
40	14.7	1.624	874	1419	35.18
45	14.7	1.624	877	1424	39.78
50	14.7	1.624	880	1429	44.06
60	14.7	1.624	885	1437	52.59
70	14.7	1.624	889	1444	61.07
75	14.7	1.624	891	1447	65.30
90	14.7	1.624	895	1454	77.94
100	14.7	1.624	898	1459	86.34
115	14.7	1.624	902	1466	98.76
135	14.7	1.624	906	1472	115.61
155	14.7	1.624	910	1478	132.21
165	14.7	1.624	912	1481	140.46
215	14.7	1.624	919	1493	181.58

Napier's approximate formula for the outflow of steam into the atmosphere, when the pressure of the atmosphere receiving the steam is less than 58 per cent of the initial pressure, is $W = ap \div 70$, where W is weight discharged, in pounds per second, a = area of orifice in square inches, and p = absolute initial pressure in pounds per square inch.

Flow of Steam in Pipes. The most generally accepted formula for the flow of steam in pipes is

$$W = 87\sqrt{\frac{w(p_1 - p_2)d^5}{L\left(1 + \frac{3.6}{d}\right)}} \qquad (1)$$

or

$$p_1 - p_2 = 0.000132\left(1 + \frac{3.6}{d}\right)\frac{W^2L}{wd^5} \qquad (2)$$

where W = weight of steam in pounds per minute;
p_1 = initial pressure in pounds per square inch;
p_2 = final pressure in pounds per square inch;
L = length of pipe in feet;
d = inside diameter of pipe in inches;
w = density of steam in pounds per cubic foot.

The quantity of steam flowing with a given drop in pressure may be calculated by formula (1), while the drop for a given flow may be obtained from formula (2). The following table computed by E. C. Sickles (Trans. A. S. M. E., XX, 354) is calculated by a formula which,

when reduced to a form similar to that of formula (1), gives a coefficient 87.45 instead of 87.

Table I gives the discharge in pounds per minute for pipes of various diameters corresponding to drops of pressure as given in Table II. The drops of pressure are computed for a length of 1000 feet; for any other length the drop is proportional to the length divided by 1000. In using the table the absolute pressure should be taken as the mean of the initial and final pressures in computing the carrying capacity.

Table I. — Steam in Pounds per Minute, Corresponding to Drop in Pressure in Table II.

Diameter Line	24	22	20	18	16	15	14	13	12	11	10
1	14 000	11 188	8772	6678	4923	4163	3481	2871	2328	1853	1443
2	13 000	10 392	8144	6203	4573	3867	3233	2667	2165	1721	1341
3	12 000	9 593	7517	5724	4220	3569	2983	2461	1996	1589	1237
4	11 000	8 804	6891	5247	3868	3271	2736	2256	1830	1456	1134
5	10 000	7 992	6265	4770	3517	2974	2486	2051	1663	1324	1031
6	9 500	7 705	5947	4532	3341	2825	2362	1940	1580	1258	979
7	9 000	7 205	5638	4293	3165	2676	2237	1846	1497	1192	928
8	8 500	6 905	5321	4054	2989	2527	2113	1743	1414	1125	876
9	8 000	6 506	5012	3816	2814	2379	1989	1640	1331	1059	825
10	7 500	6 106	4695	3577	2638	2230	1865	1538	1248	993	773
11	7 000	5 707	4385	3339	2462	2082	1740	1435	1164	927	722
12	6 500	5 307	4069	3100	2286	1933	1616	1333	1081	860	670
13	6 000	4 908	3758	2862	2110	1784	1492	1230	998	794	619
14	5 500	4 508	3443	2623	1934	1635	1368	1128	915	728	567
15	5 000	4 108	3132	2385	1758	1487	1243	1025	832	662	516

Diameter Line	9	8	7	6	5	4	3½	3	2½	2	1½	1
1	1093	799	560	371	227	123	71.6	55.9	28.8	18.1	6.81	2.52
2	1015	742	521	344	210	114.6	68.6	51.9	27.6	16.8	6.52	2.34
3	937	685	481	318	194	106.0	65.6	47.9	26.4	15.5	6.24	2.16
4	859	628	441	292	178	97.0	62.7	43.9	25.2	14.2	5.95	1.98
5	781	571	401	265	162	88.2	59.7	39.9	24.0	12.9	5.67	1.80
6	742	542	381	252	154	83.8	56.5	37.9	22.8	12.3	5.29	1.71
7	703	514	361	239	146	79.4	53.5	35.9	21.6	11.6	5.00	1.62
8	664	485	341	226	138	75.0	50.5	33.9	20.4	10.9	4.72	1.53
9	625	457	321	212	130	70.6	47.6	31.9	19.2	10.3	4.43	1.44
10	586	428	301	199	122	66.2	44.5	29.9	18.0	9.68	4.15	1.35
11	547	400	281	186	113	61.7	41.6	27.9	16.8	9.03	3.86	1.26
12	508	371	261	172	105	57.3	38.6	25.9	15.6	8.38	3.68	1.17
13	469	343	241	159	97.2	52.9	35.6	23.9	14.4	7.74	3.40	1.08
14	430	314	221	146	89.1	48.5	32.6	21.9	13.2	7.10	3.11	0.99
15	390	286	200	132	81.0	44.1	29.6	20.0	12.0	6.45	2.83	0.90

Table II. — Drop in Pressure in Pounds per Square Inch, per 1000 Feet Length, Corresponding to Discharge in Table I

Density	0.208	0.230	0.273	0.295	0.316	0.338	0.401	0.443	0.485	0.548
Pressure	90	100	120	130	140	150	180	200	220	250
Line										
1	18.1	16.4	13.8	12.8	11.9	11.1	9.39	8.50	7.76	6.87
2	15.6	14.1	11.9	11.0	10.3	9.60	8.09	7.33	6.69	5.92
3	13.3	12.0	10.1	9.38	8.75	8.18	6.90	6.24	5.70	5.05
4	11.1	10.0	8.46	7.83	7.31	6.83	5.76	5.21	4.76	4.21
5	9.25	8.36	7.5	6.52	6.09	5.69	4.80	4.34	3.97	3.51
6	8.33	7.53	6.35	5.87	5.48	5.13	4.32	3.91	3.57	3.16
7	7.48	6.76	5.70	5.27	4.92	4.60	3.88	3.51	3.21	2.84
8	6.67	6.03	5.08	4.70	4.39	4.10	3.46	3.13	2.86	2.53
9	5.91	5.35	4.50	4.17	3.89	3.64	3.07	2.78	2.53	2.24
10	5.19	4.69	3.95	3.66	3.42	3.19	2.69	2.44	2.23	1.97
11	4.52	4.09	3.44	3.19	2.98	2.78	2.34	2.12	1.94	1.72
12	3.90	3.53	2.97	2.75	2.57	2.40	2.02	1.83	1.67	1.48
13	3.32	3.00	2.53	2.34	2.19	2.04	1.72	1.56	1.42	1.26
14	2.79	2.52	2.13	1.97	1.84	1.72	1.45	1.31	1.20	1.06
15	2.31	2.09	1.76	1.63	1.52	1.42	1.20	1.08	0.991	0.877

Density in pounds per cubic foot. Pressure in pounds per square inch absolute.

Examples in the Use of the Table. Suppose it is required to find the discharge from a 5-inch pipe line, steam pressure being 120 pounds per square inch absolute, and the loss in pressure being 4.5 pounds per 1000 feet length. In Table II we find the drop 4.5 under 120 pounds pressure to be in line 9. In Table I in line 9 under 5-inch diameter we find the discharge to be 130 pounds per minute.

Or, suppose it is required to find the size of pipe to carry 1000 pounds of steam per minute, mean absolute pressure being 130 pounds and the drop in pressure being assumed as 11 pounds. In Table II the drop 11 under 130 pounds pressure is in line 2. In Table I in line 2 the tabular quantity which corresponds nearest to 1000 is in the 9-inch column. A 9-inch line will, therefore, be required.

Kent modifies Darcy's Formula for flow of water to make it apply to steam, and gives for the flow,

$$Q = c\sqrt{\frac{(p_1 - p_2)d^5}{wL}},$$

$$W = c\sqrt{\frac{w(p_1 - p_2)d^5}{L}},$$

where Q = volume of steam in cubic feet per minute;
W = weight of steam in pounds per minute;
p_1 = initial pressure in pounds per square inch;
p_2 = final pressure in pounds per square inch;
L = length of pipe in feet;
d = inside diameter of pipe in inches;
w = density of steam in pounds per cubic foot;
c = coefficient, depending on the diameter of the pipe.

The values of c are as follows:

Nominal diameter, inches	½	¾	1	1¼	1½	2	2½	3
Value of c	36.8	42	45.3	48	50	52.7	54.8	56.2
Nominal diameter, inches	**3½**	**4**	**4½**	**5**	**6**	**7**	**8**	**9**
Value of c	57.1	57.8	58.3	58.7	59.5	60.2	60.8	61.3
Nominal diameter, inches	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**
Value of c	61.7	62.1	62.3	62.6	62.7	62.9	63.2	63.2

Flow of Steam in Low-pressure Heating Lines. The following table by W. Kent (A. S. H. V. E., 1907) is based on his adaptation of Darcy's formula for flow of water to the flow of steam as given above. The drop in pressure assumed is 1 pound per 1000 feet, as a basis from which the flow at any drop may be calculated.

Flow of Steam at Low Pressure in Pounds per Hour for a Uniform Drop at the Rate of 1 Pound per 1000 Feet Length of Straight Pipe

Nominal diameter of pipe	Initial steam pressure, pounds (gage)								
	0.3	1.3	2.3	3.3	4.3	5.3	6.3	8.3	10.3
	Flow of steam, pounds per hour								
Ins.									
½	4.2	4.3	4.4	4.6	4.7	4.8	4.9	5.1	5.3
¾	9.7	10.0	10.3	10.5	10.8	11.0	11.3	11.8	12.3
1	19.0	19.6	20.2	20.7	21.2	21.7	22.3	23.2	24.2
1¼	40.1	41.3	42.5	43.7	44.8	45.9	46.9	49.0	50.9
1½	61.4	63.2	65.1	66.8	68.6	70.3	71.9	75.0	78.0
2	120.8	124.5	128.2	131.6	135.0	138.3	141.5	147.7	153.6
2½	195.7	201.8	207.5	213.2	218.7	224.0	229.2	239.2	248.8
3	345.5	356.1	366.5	376.4	386.1	395.5	404.7	422.4	439.3
3½	505.3	520.8	535.9	550.5	564.7	578.5	591.8	618.0	642.6
4	701.4	723.0	744.0	764.4	784.2	803.4	822.0	857.4	891.6
4½	938.7	967.6	995.8	1023.	1049.	1075.	1100.	1148.	1193.
5	1252.	1291.	1328.	1364.	1399.	1433.	1467.	1531.	1592.
6	2011.	2074.	2134.	2192.	2248.	2303.	2356.	2459.	2557.
7	2936.	3027.	3115.	3199.	3281.	3362	3440.	3590.	3733.
8	4082.	4208.	4331.	4448.	4564.	4674.	4783.	4991.	5191.
9	5462.	5630.	5794.	5951.	6102	6252.	6396.	6678.	6942.
10	7314.	7536.	7758.	7968.	8172.	8370.	8562.	8940.	9294.
12	11550.	11916.	12264.	12594.	12918.	13236.	13542.	14136.	14700.

For any other drop of pressure per 1000 feet length, multiply the figures in the table by the square root of that drop.

Kent says, "In all cases the judgment of the engineer must be used in the assumption of the drop to be allowed. For small distributing pipes it will generally be desirable to assume a drop of not more than

one pound per 1000 feet to insure that each single radiator shall always have an ample supply for the worst conditions, and in that case the size of piping given in the table up to two inches may be used; but for main pipes supplying totals of more than 500 square feet, greater drops may be allowed."

Resistance Due to Entrance, Bends and Valves. Mr. Briggs states, in "Warming Buildings by Steam," that the resistance at the entrance to a pipe consists of two parts, namely, the head $\frac{v^2}{2g}$ which is necessary to create the velocity of flow, and the head $0.505\frac{v^2}{2g}$, which overcomes the resistance to entrance offered by the mouth of the pipe. The total loss of head at entrance then equals the sum of these, or $1.505\frac{v^2}{2g}$, in which v = velocity of flow of steam in the pipe, in feet per second, and g = acceleration due to gravity, or 32.2.

The Babcock & Wilcox Co. state in "Steam" that the resistance at the opening, and that at a globe valve, are each about the same as that caused by an additional length of straight pipe, as computed by the formula,

$$L = \frac{114 D}{1 + (3.6 \div D)},$$

where L is the additional length of pipe in inches and D is the diameter of pipe in inches. From this formula has been computed the following table:

D in inches..........	1	1½	2	2½	3	3½	4	5	6
L in feet............	2	4	7	10	13	16	20	28	36
D in inches..........	7	8	10	12	15	18	20	22	24
L in feet............	44	53	70	88	115	143	162	181	200

The resistance to flow at a right-angled elbow is about equal to ⅜ that of a globe valve.

The above values are to be considered as being only approximations to the truth.

Expansion of Steam Pipes. The linear expansion and contraction of a pipe carrying steam, with the rise and fall of the temperature, must be taken care of by the use of some form of expansion joint or bend. To find the total expansion due to an increase in temperature, multiply the length of pipe in inches by the coefficient of expansion and by the temperature range.

The expansion for each 100 feet of length for different degrees Fahrenheit is given in the following table, which is taken from the Practical Engineer, January, 1911. The expansion for any length between two temperatures is found by taking the difference in length at these temperatures, dividing by 100 and multiplying by the length of the pipe in feet.

Expansion of Pipes

(Increase in inches per 100 feet.)

Temperature, degrees Fahrenheit	Cast iron	Wrought iron	Steel	Brass and copper
0	0.00	0.00	0.00	0.00
50	0.36	0.40	0.38	0.57
100	0.72	0.79	0.76	1.14
125	0.88	0.97	0.92	1.40
150	1.10	1.21	1.15	1.75
175	1.28	1.41	1.34	2.04
200	1.50	1.65	1.57	2.38
225	1.70	1.87	1.78	2.70
250	1.90	2.09	1.99	3.02
275	2.15	2.36	2.26	3.42
300	2.35	2.58	2.47	3.74
325	2.60	2.86	2.73	4.13
350	2.80	3.08	2.94	4.45
375	3.15	3.46	3.31	5.01
400	3.30	3.63	3.46	5.24
425	3.68	4.05	3.86	5.85
450	3.89	4.28	4.08	6.18
475	4.20	4.62	4.41	6.68
500	4.45	4.90	4.67	7.06
525	4.75	5.22	4.99	7.55
550	5.05	5.55	5.30	8.03
575	5.36	5.90	5.63	8.52
600	5.70	6.26	5.98	9.06
625	6.05	6.65	6.35	9.62
650	6.40	7.05	6.71	10.18
675	6.78	7.46	7.12	10.78
700	7.15	7.86	7.50	11.37
725	7.58	8.33	7.96	12.06
750	7.96	8.75	8.36	12.66
775	8.42	9.26	8.84	13.38
800	8.87	9.76	9.31	14.10

Sizes of Steam Pipes for Engines. A common rule is that steam pipes supplying stationary engines should be of such size that the mean velocity of steam in them does not exceed 6000 feet per minute, in order that the loss due to friction may not be excessive. There are many cases where this rule gives unnecessarily large pipes, and the velocity could be increased with advantage. The larger the pipe, the greater the surface, and the greater the amount of condensation. For large engines and high pressures it is best to assume the drop in pressure and calculate the diameter from the formulæ given above, or obtain it from the tables. In marine work the steam pipes are generally not as large as in stationary practice for the same sizes of cylinders, a velocity of 9000 feet per minute being often used. In proportioning exhaust pipes

the velocity should not exceed 4000 feet per minute for stationary engines, nor 6000 feet for marine engines.

Having assumed a velocity of flow in the pipe supplying steam to the engine, the size of pipe required is such that its area is given by the formula,

$$\text{Pipe Area} = \frac{\text{Cylinder Area} \times \text{Piston Speed}}{\text{Mean Velocity of Steam in Pipe}}.$$

Or since the areas are proportional to the squares of their diameters,

$$\text{Pipe Diameter} = \sqrt{\frac{(\text{Cylinder Diameter})^2 \times \text{Piston Speed}}{\text{Mean Velocity of Steam in Pipe}}}.$$

This assumes that steam is admitted during full stroke.

LOSS OF HEAT FROM STEAM PIPES

Loss of Heat from Bare Steam Pipes. A bare pipe carrying steam and made of steel, iron or other conducting material, loses heat by convection to the surrounding air and by radiation to the surrounding objects, both of which cause a loss of steam by condensation.

For bare steam pipes this loss may be taken as 2.7 B.T.U. per hour per square foot of surface per degree Fahrenheit difference between the temperatures of the steam and the outside air. Thus, if the pressure of the steam is 120 pounds absolute, the corresponding temperature being 341°, and the temperature of the air 60°, then the loss per hour per foot length from a 4-inch steam pipe, the external surface of which is 1.178 square feet per foot of length, will be $1.178 \times (341 - 60) \times 2.7 = 894$ B.T.U.

Condensation in Bare Steam Pipes. The corresponding condensation can be found by dividing this heat quantity by the latent heat of steam at the given pressure. In the example given above, the latent heat of steam at 120 pounds pressure, absolute, is 877.2 B.T.U. Therefore the condensation per hour per foot length of pipe is $894 \div 877.2 = 1.02$ pounds.

Steam Pipe Coverings. This loss is lessened in practice by covering the steam pipe with a material that will offer a greater resistance to the flow of heat than that offered by the material of the pipe. A good material for this purpose should not suffer serious deterioration from the heat or vibration to which it would be subjected in practice; and in all cases where damage from fire might result, it should never consist of combustible matter. Any covering should be kept perfectly dry, as still water is an excellent carrier of heat.

The best insulating substance known is air confined in minute cells, and the best nonconducting coverings owe their efficiency to the numerous air cells in their structure. In general the value of a covering is inversely proportional to its weight, and other things being equal, the

incombustible mineral substances are to be preferred to combustible material. No covering should be less than one inch in thickness.

Hair or wool felt and most of the better nonconducting materials have the disadvantage of becoming charred at high temperature and partly losing their insulating power. There is also the danger of taking fire. Mineral wool, a fibrous material made from blast furnace slag, is the best noncombustible covering, but being brittle it is liable to fall to a powder when subjected to jarring.

Pipe covering may be sectional, or plastic. The former is built up in sections and attached to the pipe by bands, which allow easy removal of the covering. The latter is put on in a soft, plastic condition, and is hardened in place; it obviates joints and adheres closely to the pipe.

The following table, taken from the various sources noted, gives the results of experiments on steam pipe coverings. In almost all cases the figures given are the averages of a number of tests.

Steam Pipe Coverings

Number	Kind of covering	Size of pipe, ins.	Thickness of covering, inches	B.T.U. per square foot per hour per degree difference of temperature	Per cent heat lost	Authority
1	Bare pipe			2.7	100	
2	Mineral wool	8	1.30	0.285	10.6	Brill
3	Rock wool	8	1.60	0.256	9.5	Brill
4	Hair felt	2	0.96	0.387	14.3	Jacobus
5	Hair felt	8	0.82	0.422	15.6	Brill
6	Remanit	2	1.51	0.302	11.2	Stott
7	Remanit	2	1.30	0.363	13.4	Jacobus
8	R[illegible]	2	0.88	0.434	16.1	Jacobus
9	S[illegible]k	2	1.68	0.348	12.9	Stott
10	S[illegible]k	2	1.20	0.427	15.8	Stott
11	M[illegible]	2	2.41	0.302	11.2	Stott
12	M[illegible]a	10	1.37	0.354	13.1	Barrus
13	M[illegible]a	8	1.25	0.384	14.2	Brill
14	M[illegible]a	2	1.16	0.439	16.3	Stott
15	M[illegible]a	4	1.12	0.465	17.2	Norton
16	M[illegible]a	2	1.08	0.304	11.3	Jacobus
17	M[illegible]a	2	1.08	0.531	19.7	Barrus
18	A[illegible]s sponge felted	2	1.14	0.260	9.6	Jacobus
19	A[illegible]s sponge felted	10	1.63	0.280	10.4	Barrus
20	A[illegible]s sponge felted	2	1.21	0.490	18.1	Barrus
21	A[illegible]s sponge felted	2	1.24	0.532	19.7	Stott
22	Manville sectional	8	1.70	0.350	13.0	Brill
23	Manville sectional	4	1.25	0.453	16.8	Norton
24	Manville sectional	2	1.31	0.572	21.2	Paulding
25	Asbestos air cell	2	1.26	0.486	18.0	Stott
26	Asbestos air cell	4	1.12	0.525	19.4	Norton
27	Asbestos air cell	2	0.96	0.716	26.5	Jacobus
28	Asbestos air cell	2	1.02	0.793	29.4	Barrus
29	Asbestos fire felt	8	1.30	0.502	18.6	Brill
30	Asbestos fire felt	2	1.00	0.721	26.7	Paulding
31	Asbestos fire felt	2	0.99	0.766	28.4	Jacobus
32	Fossil meal	8	0.75	0.879	32.6	Brill
33	Riley cement	8	0.75	0.953	35.3	Brill

A brief description of some of these coverings is given below:

No. 4. A layer of asbestos paper 1/32 inch thick next to the pipe, then the hair felt, then a layer of paper, and outside of all a canvas covering.

No. 5. The hair felt was bound tightly around the pipe, with no canvas covering; it had a layer of asbestos paper under it.

No. 6. A covering composed of two layers wound in reverse direction with ropes of carbonized silk; the inner layer 2½ inches wide and ½ inch thick; the outer layer 2 inches wide and ¾ inch thick, over which was wound a network of wire; ⅛ inch asbestos next to pipe.

No. 7. A grade known as high-pressure remanit; encased in canvas.

No. 8. A grade known as intermediate-pressure remanit; encased in canvas.

Nos. 9 and 10. Solid sectional covering of granulated cork with ⅛-inch asbestos paper next to pipe.

No. 11. 85 per cent carbonate of magnesia. Average of a number of tests of moulded sectionals, thickness of covering ranging from 2.20 to 2.71 inches.

No. 12. Carbonate of magnesia with some asbestos fiber; outside finished with canvas.

No. 14. Average of tests, thickness of covering ranging from 1.12 to 1.19 inches.

No. 15. Moulded sectional covering composed of about 90 per cent carbonate of magnesia.

No. 17. Similar, except in thickness, to No. 12.

Nos. 18, 19, 20 and 21. Laminated sectional, composed of a number of layers of asbestos paper in which were imbedded small pieces of sponge.

No. 23. A sectional covering composed of an inner layer of earthy material covered by a layer of wool felt.

No. 25. Laminated sectional with ⅛-inch asbestos paper next to pipe.

No. 26. Made of thin sheets of corrugated asbestos paper, stuck together with silicate of soda.

Nos. 27 and 28. Similar to No. 26.

Nos. 32 and 33. Mixed with water and plastered on the pipe.

AIR

Properties

Flow of Air

PROPERTIES OF AIR

Air is a mechanical mixture of the gases oxygen and nitrogen with a small amount of argon. By volume its composition is 78 per cent nitrogen, 21 per cent oxygen and 1 per cent argon. Atmospheric air of ordinary purity contains about 0.04 per cent of carbon dioxide.

Weight of Air. The weight of pure air at 32° F. and a barometric pressure of 29.92 inches of mercury, or 14.6963 pounds per square inch is 0.080728 pound per cubic foot. The volume of a pound of air is therefore 12.387 cubic feet. At any other temperature and pressure its weight in pounds per cubic foot is $W = \frac{1.325 \times B}{T}$, where B = height of barometer in inches and T = absolute temperature Fahrenheit. The weight per cubic foot at various temperatures and pressures is given in the table on pages 353 and 354.

Pressure, Volume and Temperature. The relation between pressure, volume and temperature of air is such that

$$\frac{p_1 v_1}{T_1} = \frac{p_2 v_2}{T_2} = 53.3,$$

in which p_1 and p_2 are absolute pressures in pounds per square foot, v_1 and v_2 the volumes in cubic feet of 1 pound of air, and T_1 and T_2 the absolute temperatures. When the pressure remains constant the volume is directly proportional to the absolute temperature. If the temperature remains constant the volume is inversely proportional to the absolute pressure.

Pressure of the Atmosphere. The following table gives the pressure of the atmosphere in pounds per square inch and pounds per square foot for various readings of the barometer. It is based on 1 inch of mercury at 32° F. being equal to a pressure of 0.491 pound per square inch.

Pressure of the Atmosphere for Various Readings of the Barometer

Barometer, inches	Pounds per square inch	Pounds per square foot	Barometer, inches	Pounds per square inch	Pounds per square foot
28.00	13.75	1980	29.75	14.61	2103
28.25	13.87	1997	30.00	14.73	2121
28.50	13.99	2015	30.25	14.85	2139
28.75	14.12	2033	30.50	14.98	2156
29.00	14.24	2050	30.75	15.10	2174
29.25	14.36	2068	31.00	15.22	2192
29.50	14.48	2086	31.25	15.34	2210

Weight of Air at Various Pressures and Temperatures
(Based on an Atmospheric Pressure of 14.7 Pounds)

Temperature of air, degrees Fahrenheit	Gage pressure, pounds										
	0	5	10	20	30	40	50	60	70	80	90
	Weight in pounds per cubic foot										
− 20	.0900	.1205	.1515	.2125	.2744	.3360	.3970	.4580	.5190	.5800	.6410
− 10	.0882	.1184	.1485	.2090	.2685	.3283	.3880	.4478	.5076	.5674	.6272
0	.0864	.1160	.1455	.2040	.2630	.3215	.3800	.4385	.4970	.5555	.6140
10	.0846	.1136	.1425	.1995	.2568	.3145	.3720	.4292	.4863	.5433	.6006
20	.0828	.1112	.1395	.1955	.2516	.3071	.3645	.4205	.4770	.5330	.5890
30	.0811	.1088	.1366	.1916	2465	.3015	.3570	.4121	.4672	.5221	.5771
40	.0795	.1067	.1338	.1876	.2415	.2954	.3503	.4038	.4576	.5114	.5652
50	.0780	.1045	.1310	.1839	.2367	.2905	3432	.3960	.4487	.5014	.5541
60	.0764	.1025	.1283	.1803	.2323	.2840	.3562	.3882	.4402	.4927	.5447
70	.0750	.1005	.1260	.1770	.2280	.2791	.3302	.3808	.4316	.4824	.5332
80	.0736	.0988	.1239	.1738	.2237	.2739	.3242	.3738	.4234	.4729	.5224
90	.0723	.0970	.1218	.1707	.2195	.2688	.3182	.3670	.4154	.4639	.5122
100	.0710	.0954	.1197	.1676	.2155	.2638	.3122	.3602	.4079	.4555	.5033
110	.0698	.0937	.1176	.1645	.2115	.2593	.3070	.3542	.4011	.4481	.4950
120	.0686	.0921	.1155	.1618	.2080	.2549	.3018	.3481	.3944	.4403	.4866
130	.0674	.0905	.1135	.1590	.2045	.2505	.2966	.3446	.3924	.4296	.4770
140	.0663	.0889	.1115	.1565	.2015	.2465	.2915	.3364	.3813	.4262	.4711
150	.0652	.0874	.1096	.1541	.1985	.2425	.2865	.3308	.3751	.4193	.4636
175	.0626	.0840	.1054	.1482	.1910	.2335	.2755	.3181	.3607	.4033	.4450
200	.0603	.0809	.1014	.1427	.1840	.2248	.2655	.3054	.3473	.3882	.4291
225	.0581	.0779	.0976	.1373	.1770	.2163	.2555	.2949	.3344	.3738	.4129
250	.0560	.0751	.0941	.1323	.1705	.2085	.2466	.2845	.3223	.3602	.3981
275	.0541	.0726	.0910	.1278	.1645	.2011	.2378	.2745	.3111	.3478	.3844
300	.0523	.0707	.0881	.1237	.1592	.1945	.2300	.2654	.3008	.3362	.3716
350	.0491	.0658	.0825	.1160	.1495	.1828	.2160	.2492	.2824	.3156	.3488
400	.0463	.0621	.0779	.1090	.1405	.1720	.2035	.2348	.2661	.2974	.3287
450	.0437	.0586	.0735	.1033	.1330	.1628	.1925	.2220	.2515	.2810	.3105
500	.0414	.0555	.0696	.0978	.1260	.1540	.1820	.2100	.2380	.2660	.2940
550	.0394	.0528	.0661	.0930	.1198	.1464	.1730	.1996	.2262	.2528	.2794
600	.0376	.0504	.0631	.0885	.1140	.1395	.1650	.1904	.2158	.2412	.2668

Weight of Air at Various Pressures and Temperatures (Concluded)
(Based on an Atmospheric Pressure of 14.7 Pounds)

Temperature of air, degrees Fahrenheit	Gage pressure, pounds										
	100	110	120	130	140	150	175	200	225	250	300
	Weight in pounds per cubic foot										
−20	.702	.764	.825	.886	.948	1.010	1.165	1.318	1.465	1.625	1.930
−10	.687	.747	.807	868	.928	989	1.139	1.288	1.438	1.588	1.890
0	.672	.731	.790	.849	.908	.968	1.114	1.260	1.406	1.553	1.850
10	.658	.716	.774	.832	.889	.947	1.090	1.233	1.376	1.520	1.810
20	.645	.701	.757	.813	.869	.927	1.067	1.208	1.348	1.489	1.770
30	.632	.687	.742	.797	.852	.908	1.046	1.184	1.322	1.460	1.735
40	.619	.673	.727	.781	.835	.890	1.025	1.161	1.296	1.431	1.701
50	.607	.660	.713	.766	.819	.873	1.006	1.139	1.271	1.403	1.668
60	.596	.649	.700	.752	.804	.856	.988	1.116	1.245	1.376	1.636
70	.584	.635	.686	.737	.788	.839	.967	1.095	1.223	1.350	1.604
80	.572	.622	.673	.723	.774	.824	.949	1.074	1.199	1.325	1.573
90	.561	.611	.660	.709	.759	.809	.932	1.054	1.177	1.300	1.544
100	.551	.599	.648	.696	.745	.794	.914	1.035	1.155	1.276	1.517
110	.542	.589	.637	.685	.732	.780	.899	1.017	1.135	1.254	1.491
120	.533	.579	.626	.673	.720	.767	.884	1.001	1.118	1.234	1.465
130	.524	.570	.616	.662	.708	.754	.869	.984	1.099	1.214	1.440
140	.516	.561	.606	.651	.696	.742	.855	.968	1.081	1.194	1.416
150	.508	.552	.596	.640	.685	.730	.841	.953	1.064	1.175	1.392
175	.488	.531	.573	.6 6	.658	.701	.808	.914	1.021	1.128	1.337
200	.470	.511	.552	.592	.633	.674	.776	.879	.982	1.084	1.287
225	.452	.491	.531	.570	.609	.649	.747	.846	.944	1.043	1.240
250	.436	.474	.513	.551	.589	.627	.722	.817	.912	1.007	1.197
275	.421	.458	.494	.531	.568	.605	.697	.789	.881	.972	1.155
300	.407	.442	.478	.513	.549	.585	.673	.762	.852	.940	1.118
350	.382	.415	.449	.482	.516	.549	.632	.715	.799	.883	1.048
400	.360	.391	.423	.454	.486	.517	.596	.674	.753	.831	.987
450	.340	.369	.399	.429	.458	.488	.562	.637	.711	.786	.934
500	.322	.351	.379	.407	.435	.463	.534	.604	.675	.746	.885
550	.306	.333	.359	.386	.413	.440	.507	.573	.641	.749	.841
600	.292	.317	.343	.368	.393	.419	.483	.547	.611	.675	.801

Specific Heat of Air. The specific heat of a gas is the heat, in heat units, required to raise the temperature of one pound of the gas one degree Fahrenheit. The mean specific heat of air at constant pressure is $c_p = 0.2375$ and at constant volume is $c_v = 0.1689$.

Adiabatic Expansion and Compression. Adiabatic expansion or compression of a gas means that the gas is expanded or compressed without transmission of heat to or from the gas. This would be the case were the expansion or compression to take place in an absolutely non-conducting cylinder, in which case the temperature, pressure and volume of air would vary as indicated by the following formulæ:

$$\frac{v_2}{v_1} = \left(\frac{p_1}{p_2}\right)^{0.71} \qquad \frac{p_2}{p_1} = \left(\frac{v_1}{v_2}\right)^{1.41} \qquad \frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{0.41}$$

$$\frac{v_2}{v_1} = \left(\frac{T_1}{T_2}\right)^{2.46} \qquad \frac{p_2}{p_1} = \left(\frac{T_2}{T_1}\right)^{3.46} \qquad \frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{0.29}$$

in which p_1, v_1 and T_1 = initial absolute pressure, volume and absolute temperature, and p_2, v_2 and T_2 = final absolute pressure, volume and absolute temperature of the air after compression. The manner in which the temperature and volume vary with the change in pressure is shown in the following table:

Table for Adiabatic Compression or Expansion of Air

(Proc. Inst. M. E., Jan., 1881, p. 123.)

Absolute pressure		Absolute temperature		Volume	
$\frac{p_2}{p_1}$	$\frac{p_1}{p_2}$	$\frac{T_2}{T_1}$	$\frac{T_1}{T_2}$	$\frac{v_1}{v_2}$	$\frac{v_2}{v_1}$
1.2	.833	1.054	.948	1.138	.879
1.4	.714	1.102	.907	1.270	.788
1.6	.625	1.146	.873	1.396	.716
1.8	.556	1.186	.843	1.518	.659
2.0	.500	1.222	.818	1.636	.611
2.2	.454	1.257	.796	1.750	.571
2.4	.417	1.289	.776	1.862	.537
2.6	.385	1.319	.758	1.971	.507
2.8	.357	1.348	.742	2.077	.481
3.0	.333	1.375	.727	2.182	.458
3.2	.312	1.401	.714	2.284	.438
3.4	.294	1.426	.701	2.384	.419
3.6	.278	1.450	.690	2.483	.403
3.8	.263	1.473	.679	2.580	.388
4.0	.250	1.495	.669	2.676	.374
4.2	.238	1.516	.660	2.770	.361
4.4	.227	1.537	.651	2.863	.349
4.6	.217	1.557	.642	2.955	.338
4.8	.208	1.576	.635	3.046	.328
5.0	.200	1.595	.627	3.135	.319
6.0	.167	1.681	.595	3.569	.280
7.0	.143	1.758	.569	3.981	.251
8.0	.125	1.828	.547	4.377	.228
9.0	.111	1.891	.529	4.759	.210
10.0	.100	1.950	.513	5.129	.195

Work of Adiabatic Compression of Air. If air is compressed from a volume v_1 and pressure p_1, to a volume v_2 and pressure p_2, in a non-conducting cylinder without clearance, the work involved in delivering one pound is as follows:

$$\text{Work of compression} = 2.46\, p_1v_1 \left[\left(\frac{v_1}{v_2}\right)^{0.41} - 1\right]$$

$$= 2.46\, p_1v_1 \left[\left(\frac{p_2}{p_1}\right)^{0.29} - 1\right].$$

$$\text{Work of expulsion} = p_2v_2 = p_1v_1 \left(\frac{p_2}{p_1}\right)^{0.29}.$$

Total work is the sum of the work of compression and expulsion less the work, p_1v_1, of the atmosphere done on the piston during admission, or

$$\text{Total work} = 3.46\, p_1v_1 \left[\left(\frac{p_2}{p_1}\right)^{0.29} - 1\right].$$

The mean effective pressure equals the total work ÷ the initial volume, v_1, or

$$3.46\, p_1 \left[\left(\frac{p_2}{p_1}\right)^{0.29} - 1\right].$$

Isothermal Expansion and Compression. Isothermal expansion or compression of a gas means that the gas is expanded or compressed with the addition or rejection of sufficient heat to maintain a constant temperature. The temperature being constant the pressure and volume will vary according to the law

$$p_1v_1 = p_2v_2 = C,$$

in which p_1 and p_2 are the initial and final absolute pressures in pounds per square foot, v_1 and v_2 are the initial and final volumes in cubic feet, and C is a constant depending on the temperature. For a temperature of 32° F. this constant is 26 214 foot-pounds, and for isothermals corresponding to other temperatures it may be found from the formula $C = 53.3\, T$, in which T is the absolute temperature of the isothermal.

Work of Isothermal Compression of Air. If air is compressed from a volume v_1 and pressure p_1 to a volume v_2 and pressure p_2, in a cylinder without clearance, in such manner as to keep the temperature constant, the work involved in delivering one pound is as follows:

$$\text{Work of compression} = p_1v_1 \log_e \frac{v_1}{v_2}.$$

$$\text{Work of expulsion} = p_2v_2 = p_1v_1.$$

The total work then is the sum of the work of compression and expulsion less the work, p_1v_1, of the atmosphere done on the piston during admission, or

$$\text{Total work} = p_1v_1 \log_e \frac{v_1}{v_2} + p_1v_1 - p_1v_1 = p_1v_1 \log_e \frac{v_1}{v_2}.$$

In this formula, Naperian, or hyperbolic, logarithms must be used. These may be obtained from the common logarithms by multiplying by the constant 2.303.

The mean effective pressure equals the total work divided by the initial volume v_1, or $p_1 \log_e v_1/v_2$.

FLOW OF AIR

Flow of Air under Pressure from Orifices into the Atmosphere. The following table gives the theoretical velocity for the discharge of air into the atmosphere under very low pressures, less than one-quarter of a pound per square inch. In this case the variation due to difference in air density is so small that it has not been considered. These theoretical velocities are to be reduced by multiplying by a coefficient c, varying with the form of the orifice. For an orifice with a sharp edge in a thin plate c is 0.65, for a plate with rounded orifice on the inside c is from 0.70 to 0.75, and for a nozzle of good form c may be taken as 0.93.

Velocity of Air Under Low Pressures
(Temperature 62° F. Barometer 30 inches.)

Pressure		Theoretical velocity, feet per second	Pressure		Theoretical velocity, feet per second
Inches of water	Pounds per square foot		Inches of water	Pounds per square foot	
.01	.052	6.61	.8	4.15	59.1
.02	.104	9.35	.9	4.67	62.7
.04	.208	13.2	1.0	5.19	66.1
.07	.363	17.4	1.5	7.79	80.9
.10	.519	20.9	2.0	10.38	93.5
.20	1.038	29.5	2.5	12.98	104.0
.30	1.558	36.2	3.0	15.58	114.0
.40	2.077	41.8	3.5	18.18	124.0
.45	2.337	44.3	4.0	20.77	132.0
.50	2.597	46.7	4.5	23.37	140.0
.60	3.116	51.2	5.0	25.97	148.0
.70	3.635	55.3	6.0	31.16	162.0

For the velocity of air under higher pressures discharging into the atmosphere, Hiscox in "Compressed Air" gives the following table:

Velocity of Efflux of Compressed Air

Pressure			Theoretical velocity, feet per second	Pressure			Theoretical velocity, feet per second
Atmospheres	Inches of mercury	Pounds per square inch		Atmospheres	Inches of mercury	Pounds per square inch	
010	0.30	0.147	94.4	.680	20.4	10.	780
.066	2.10	1.00	246.	.809	24.28	12.	855
.100	3.00	1.47	299.	1.	30.	14.7	946
.136	4.08	2.00	348.	2.	60.	29.4	1094
.204	6.12	3.00	472.	5.	150.	73.5	1219
.272	8.16	4.00	493.	10.	300.	147.	1275
.340	10.20	5.00	552.	20.	600.	294.	1304
.408	12.24	6.00	604.	40.	1200.	588.	1323
.500	15.00	7.35	673.	100.	3000.	1470.	1331
.544	16.32	8.00	697.	200.	6000.	2940.	1334
.611	18.34	9.00	741.				

To obtain the actual velocity, this theoretical velocity should be multiplied by a coefficient varying with the nature of the orifice and the air pressure. The coefficients for an orifice in a thin plate and for a short tube whose length is three times its diameter are given below. The pressures are in atmospheres above atmospheric pressure.

Coefficients of Air Discharge

	Pressure in atmospheres						
	.01	.1	.5	1.	5.	10.	100.
Orifice in thin plate........	.65	.64	.57	.54	.45	.436	.423
Short tube................	.834	.82	.71	.67	.53	.51	.487

The quantity of air discharged into the atmosphere from a round hole in a receiver in cubic feet of free air per minute is given in the following table:

Discharge of Air Through an Orifice
(Ingersoll-Rand Company.)

Diameter of orifice, inches	Receiver gage pressure, pounds per square inch								
	2	5	10	15	20	25	30	35	40
1/64	.038	.0597	.0842	.103	.119	.133	.156	.173	.19
1/32	.153	.242	.342	.418	.485	.54	.632	.71	.77
1/16	.647	.965	1.36	1.67	1.93	2.16	2.52	2.80	3.07
1/8	2.435	3.86	5.45	6.65	7.7	8.6	10.	11.2	12.27
1/4	9.74	15.4	21.8	26.7	30.8	34.5	40.	44.7	49.09
3/8	21.95	34.6	49.	60.	69.	77.	90.	100.	110.45
1/2	39.0	61.6	87.	107.	123.	138.	161.	179.	196.35
5/8	61.0	96.5	136.	167.	193.	216.	252.	280.	306.80
3/4	87.6	133.	196.	240.	277.	310.	362.	400.	441.79
7/8	119.5	189.	267.	326.	378.	422.	493.	550.	601.32
1	156.	247.	350.	427.	494.	550.	645.	715.	785.40
1 1/4	242.	384.	543.	665.	770.	860.	1000.		
1 1/2	350.	550.	780.	960.					
2	625.	985.							

Diameter of orifice, inches	Receiver gage pressure, pounds per square inch							
	45	50	60	70	80	90	100	125
1/64	.208	.225	.26	.295	.33	.364	.40	.486
1/32	.843	.914	1.05	1.19	1.33	1.47	1.61	1.97
1/16	3.36	3.64	4.2	4.76	5.32	5.87	6.45	7.85
1/8	13.4	14.5	16.8	19.	21.2	23.5	25.8	31.4
1/4	53.8	58.2	67.	76.	85.	94.	103.	125.
3/8	121.	130.	151.	171.	191.	211.	231.	282.
1/2	215.	232.	268.	304.	340.	376.	412.	502.
5/8	336.	364.	420.	476.	532.	587.	645.	785.
3/4	482.	522.	604.	685.	765.	843.	925.	
7/8	658.	710.	822.	930.	1004.			
1	860.	930.						

Flow of Air in Pipes. For the flow of air in pipes at or near atmospheric pressure, the following formulæ, which are deduced from Hawksley's formula, may be used.

$$v = 114.5\sqrt{\frac{hd}{L}},$$

$$h = \frac{v^2L}{13\,110d},$$

where v = velocity of air in feet per second;
h = head, in inches of water column, causing flow, or the loss of head for a given flow;
d = inside diameter of pipe, in inches;
L = length of pipe, in feet.

The formulæ used by the B. F. Sturtevant Company, derived from Weisbach, are given below. They correspond to Hawksley's formula with a coefficient 120.1 instead of 114.5.

$$v = \sqrt{\frac{25\,000\,dp}{L}},$$

$$p = \frac{Lv^2}{25\,000\,d},$$

where v = velocity in feet per second;
p = loss of pressure, in ounces per square inch;
d = inside diameter of pipe, in inches;
L = length of pipe, in feet.

The quantity of air discharged in cubic feet per second is the product of the velocity, as obtained above, and the area of the pipe in square feet. The horse-power required to drive air through a pipe is the volume in cubic feet per second multiplied by the pressure in pounds per square foot and divided by 550.

The following table condensed from one given in the catalogue of the B. F. Sturtevant Company gives the loss in pressure by friction of air in pipes 100 feet long; for any other length the loss is directly proportional.

Loss of Pressure in Pipes

Velocity, feet per minute	Diameter of pipe in inches											
	1	2	3	4	5	6	7	8	9	10	11	12
	Loss in ounces per square inch per 100 feet											
600	0.400	0.200	0.133	0.100	0.080	0.067	0.057	0.050	0.044	0.040	0.036	0.033
1200	1.600	0.800	0.533	0.400	0.320	0.267	0.229	0.200	0.178	0.160	0.145	0.133
1800	3.600	1.800	1.200	0.900	0.720	0.600	0.514	0.450	0.400	0.360	0.327	0.300
2400	6.400	3.200	2.133	1.600	1.280	1.067	0.914	0.800	0.711	0.640	0.582	0.533
3000	10.000	5.000	3.333	2.500	2.000	1.667	1.429	1.250	1.111	1.000	0.909	0.833
3600	14.400	7.200	4.800	3.600	2.880	2.400	2.057	1.800	1.600	1.440	1.309	1.200
4200	......	9.800	6.533	4.900	3.920	3.267	2.800	2.450	2.178	1.960	1.782	1.633
4800	......	12.800	8.533	6.400	5.120	4.267	3.657	3.200	2.844	2.560	2.327	2.133
6000	......	20.000	13.333	10.000	8.000	6.667	5.714	5.000	4.444	4.000	3.636	3.333

Loss of Pressure in Pipes (Concluded)

Velocity, feet per minute	Diameter of pipe in inches — Loss in ounces per square inch per 100 feet											
	14	16	18	20	22	24	28	32	36	40	44	48
600	.029	.025	.022	.020	.018	.017	.014	.012	.011	.010	.009	.008
1200	.114	.100	.089	.080	.073	.067	.057	.050	.044	.040	.036	.033
1800	.257	.225	.200	.180	.164	.150	.129	.112	.100	.090	.082	.075
2400	.457	.400	.356	.320	.291	.267	.239	.200	.178	.160	.145	.133
3000	.714	.625	.556	.500	.455	.417	.357	.312	.278	.250	.227	.208
3600	1.029	.900	.800	.720	.655	.600	.514	.450	.400	.360	.327	.300
4200	1.400	1.225	1.089	.980	.891	.817	.700	.612	.544	.490	.445	.408
4800	1.829	1.600	1.422	1.280	1.164	1.067	.914	.800	.711	.640	.582	.533
6000	2.857	2.500	2.222	2.000	1.818	1.667	1.429	1.250	1.111	1.000	.909	.833

Flow of Compressed Air in Pipes. In considering the flow of compressed air in pipes the density of the air should be taken into account. A common formula, which can be used only when the difference of pressure at the two ends of the pipe is small and the density of the air, therefore, nearly constant, is

$$Q = 58\sqrt{\frac{pd^5}{wL}},$$

where Q = volume, in cubic feet per minute;
p = difference in pressure, in pounds per square inch;
d = inside diameter of pipe, in inches;
w = density of entering air, in pounds per cubic foot;
L = length of pipe, in feet.

In long pipes with large differences of pressure, the density decreases and the volume and velocity increase during the flow from one end of the pipe to the other. For the flow of air under such conditions see under the flow of high pressure gas in pipes, page 320.

Loss of Pressure in Compressed Air Transmission. The following tables, which are taken from the catalogue of the Ingersoll-Rand Company, give the drop in pressure for different deliveries at various pressures for sizes of pipe from 1 inch to 16 inches. The loss is given for 1000 feet length of pipe; for any other length the loss is directly proportional.

Flow of Compressed Air at 60 Pounds Gage

(Loss of Pressure in Pounds per 1000 Feet.)

Size of pipe	Delivery in cubic feet of compressed air per minute at 60 pounds gage									
	9.84	14.73	19.64	24.60	29.45	34.44	39.35	49.20	58.90	78.6
	Equivalent delivery in cubic feet of free air per minute									
	50	75	100	125	150	175	200	250	300	400
1	18.24									
1¼	5.06	11.34	20.16							
1½	1.95	4.33	7.79	12.23	17.53					
2	.42	.95	1.69	2.65	3.80	5.17	6.77	10.61	15.20	
2½	.13	.29	.52	.81	1.16	1.58	2.09	3.24	4.65	8.28
3	.05	.11	.19	.30	.44	.59	.78	1.22	1.78	3.11
3½	......	.05	.08	.13	.19	.26	.36	.55	.78	1.40
4	......	......	.04	.07	.09	.13	.17	.27	.38	.69
4½	......	......	......	.03	.05	.07	.09	.15	.21	.39
5	......	......	......	......	.03	.04	.06	.08	.12	.22
6	......	......	......	......	......	.01	.02	.03	.05	.08
7	......	......	......	......	......	......	.01	.01	.02	.04
8	......	......	......	......	......	......	......	......	.01	.01

Size of pipe	Delivery in cubic feet of compressed air per minute at 60 pounds gage									
	98.4	118.1	156.6	196.4	294.5	393.7	492	589	786	984
	Equivalent delivery in cubic feet of free air per minute									
	500	600	800	1000	1500	2000	2500	3000	4000	5000
3	4.88	7.03								
3½	2.20	3.17	5.57	8.77						
4	1.08	1.56	2.75	4.33	9.73					
4½	.60	.87	1.52	2.40	5.39	9.65				
5	.34	.49	.87	1.37	3.08	5.51	8.61			
6	.14	.19	.34	.54	1.20	2.16	3.36	4.82		
7	.06	.09	.15	.24	.55	.98	1.53	2.19	3.91	6.19
8	.03	.04	.08	.12	.27	.41	.77	1.11	1.98	3.10
9	.01	.02	.04	.06	.15	.27	.42	.61	1.08	1.69
10	......	.01	.03	.04	.09	.16	.25	.36	.63	.99
12	......	......	.01	.02	.03	.06	.09	.14	.25	.39
14	......	......	......	.01	.01	.03	.04	.06	.11	.18
16	......	......	......	......	......	.01	.02	.03	.05	.09

Flow of Compressed Air at 80 Pounds Gage

(Loss of Pressure in Pounds per 1000 Feet.)

Size of pipe	Delivery in cubic feet of compressed air per minute at 80 pounds gage									
	7.74	11.3	15.2	19.4	23.2	27.2	31.0	38.7	46.5	62.0
	Equivalent delivery in cubic feet of free air per minute									
	50	75	100	125	150	175	200	250	300	400
1	14.31									
1¼	3.96	8.46	15.31							
1½	1.53	3.26	5.92	9.64	13.79					
2	.33	.71	1.28	2.09	2.99	4.09	5.34	8.32	12.01	
2½	.10	.21	.39	.64	.91	1.25	1.63	2.54	3.67	6.53
3	.03	.08	.14	.24	.34	.47	.61	.96	1.38	2.45
3½	.01	.03	.06	.11	.15	.21	.27	.43	.62	1.11
4	......	.01	.03	.05	.07	.10	.13	.21	.30	.54
4½	......	......	.02	.03	.04	.06	.07	.12	.17	.30
5	......	......	.01	.01	.02	.03	.04	.07	.09	.17
6	......	......	......	......	.01	.01	.01	.02	.03	.06
7	......	......	......	......	......	......	......	.01	.01	.03
8	......	......	......	......	......	......	......	......	......	.01

Size of pipe	Delivery in cubic feet of compressed air per minute at 80 pounds gage									
	77.4	92.9	124.0	152	232	310	387	465	620	774
	Equivalent delivery in cubic feet of free air per minute									
	500	600	800	1000	1500	2000	2500	3000	4000	5000
2½	10.81									
3	3.83	5.61	9.86							
3½	1.73	2.46	4.42	6.64	15.41					
4	.85	1.22	2.18	3.29	7.62	13.62				
4½	.47	.68	1.19	1.82	4.24	7.58	11.79			
5	.27	.39	.69	1.04	2.43	4.32	6.88	9.72		
6	.10	.15	.27	.40	.95	1.69	2.64	3.79	6.78	10.55
7	.05	.06	.12	.18	.43	.77	1.19	1.73	3.07	4.79
8	.02	.03	.06	.09	.22	.39	.60	.87	1.55	2.46
9	.01	.02	.03	.05	.12	.21	.33	.48	.85	1.33
10	......	.01	.02	.03	.06	.12	.19	.28	.49	.77
12	......	......	.01	.01	.02	.04	.07	.11	.19	.30
14	......	......	......	......	.01	.02	.03	.05	.09	.14
16	......	......	......	......	......	.01	.01	.02	.04	.07

Flow of Compressed Air at 100 Pounds Gage

(Loss of Pressure in Pounds per 1000 Feet.)

Size of pipe	Delivery in cubic feet of compressed air per minute at 100 pounds gage									
	6.41	9.61	12.81	15.81	19.22	22.39	25.62	31.62	38.44	51.24
	Equivalent delivery in cubic feet of free air per minute									
	50	75	100	125	150	175	200	250	300	400
1	11.89									
1¼	3.29	7.42	13.20							
1½	1.28	2.87	5.11	7.75	11.42					
2	.27	.62	1.15	1.68	2.48	3.36	4.43	6.72	9.95	
2½	.08	.19	.34	.52	.76	1.03	1.36	2.06	3.04	5.40
3	.03	.07	.12	.19	.29	.39	.51	.77	1.14	2.06
3½	.01	.03	.05	.08	.13	.17	.23	.35	.51	.92
4	......	.01	.02	.04	.06	.09	.12	.17	.25	.45
4½	......	......	.01	.02	.03	.04	.06	.09	.14	.25
5	......	......	......	.01	.02	.03	.04	.05	.08	.15
6	......	......	......	......	.01	.01	.02	.02	.03	.05
7	......	......	......	......	......	......	.01	.01	.01	.03
8	......	......	......	......	......	......	......	......	......	.01

Size of pipe	Delivery in cubic feet of compressed air per minute at 100 pounds gage									
	63.24	76.88	102.5	126.5	192.2	256.2	316.2	384.4	512.4	632.4
	Equivalent delivery in cubic feet of free air per minute									
	500	600	800	1000	1500	2000	2500	3000	4000	5000
2½	8.21	12.21								
3	3.08	4.58	8.13	12.39						
3½	1.39	2.14	3.67	5.60	12.81					
4	.68	1.03	1.81	2.76	6.68	11.35				
4½	.38	.57	1.00	1.23	3.51	6.61	9.56	14.04		
5	.22	.33	.57	.88	2.03	3.62	5.51	8.11	14.48	
6	.08	.12	.22	.34	.78	1.41	2.14	3.16	5.59	8.51
7	.04	.05	.10	.16	.36	.67	.97	1.44	2.55	3.88
8	.02	.03	.05	.08	.18	.33	.49	.76	1.30	1.98
9	.01	.02	.03	.04	.09	.18	.27	.39	.72	1.07
10	......	.01	.02	.03	.05	.10	.16	.23	.41	.63
12	......	......	.01	.01	.02	.04	.06	.09	.16	.25
14	......	......	......	......	.01	.02	.03	.04	.07	.11
16	......	......	......	......	......	.01	.01	.02	.04	.06

Flow of Compressed Air at 125 Pounds Gage
(Loss of Pressure in Pounds per 1000 Feet.)

Size of pipe	Delivery in cubic feet of compressed air per minute at 125 pounds gage									
	5.26	7.89	10.51	13.15	15.79	18.41	21.05	26.30	31.58	42.10
	Equivalent delivery in cubic feet of free air per minute									
	50	75	100	125	150	175	200	250	300	400
1	9.88	22.20	39.50							
1¼	2.70	6.07	10.82	16.88	24.33	33.05				
1½	1.05	2.37	4.22	6.58	9.47	12.90	16.84	26.30	37.90	
2	.23	.51	.91	1.42	2.04	2.78	3.63	5.68	8.18	14.51
2½	.07	.16	.28	.43	.63	.85	1.11	1.73	2.51	4.44
3	.03	.06	.10	.16	.23	.32	.42	.65	.94	1.67
3½	.01	.03	.05	.07	.11	.14	.19	.29	.42	.75
4	......	.01	.02	.04	.05	.07	.09	.15	.21	.37
4½	......	......	.01	.02	.03	.04	.05	.08	.12	.21
5	......	......	......	.01	.02	.02	.03	.05	.07	.12
6	......	......	......	......	.01	.01	.01	.02	.03	.05
7	......	......	......	......	......	......	......	.01	.01	.02
8	......	......	......	......	......	......	......	......	......	.01

Size of pipe	Delivery in cubic feet of compressed air per minute at 125 pounds gage									
	52.60	63.20	84.20	105.1	157.9	210.5	263.0	315.8	422.0	526.0
	Equivalent delivery in cubic feet of free air per minute									
	500	600	800	1000	1500	2000	2500	3000	4000	5000
2	22.68									
2½	6.95	10.00	17.80							
3	2.61	3.76	6.68	10.42	23.48					
3½	1.18	1.69	3.01	4.71	10.59	18.81	29.40			
4	.58	.84	1.49	2.32	5.23	9.30	14.52	20.90		
4½	.32	.46	.83	1.29	2.90	5.15	8.05	11.59	20.61	32.20
5	.18	.27	.47	.74	1.65	2.94	4.60	6.63	11.80	18.45
6	.07	.10	.18	.29	.64	1.15	1.80	2.59	4.61	7.20
7	.03	.05	.08	.13	.29	.52	.82	1.18	2.19	3.27
8	.02	.02	.04	.07	.15	.26	.41	.60	1.06	1.65
9	.01	.01	.02	.04	.08	.15	.23	.33	.58	.90
10	......	.01	.01	.02	.05	.08	.13	.19	.34	.53
12	......	......	.01	.01	.02	.03	.05	.07	.13	.21
14	......	......	......	......	.01	.02	.02	.03	.06	.10
16	......	......	......	......	......	.01	.01	.02	.03	.05

Effect of Bends and Fittings. The formulæ quoted above are for the flow of air through straight pipes. For the resistance due to curves, valves and fittings, see the effect of bends and fittings under the flow of gas in pipes, page 324. In this connection it is well to note that all piping and fittings for air lines should be galvanized, as the scale from black pipe finds its way to air hammers, drills and cylinders, and causes considerable trouble.

Fifth Roots and Fifth Powers

Number or root	Power	Number or root	Power	Number or root	Power	Number or root	Power	Number or root	Power
.10	.000010	2.30	64.3634	6.4	10 737	11.6	210 034	20.4	3 533 059
.15	.000075	2.35	71.6703	6.5	11 603	11.8	228 776	20.6	3 709 677
.20	.000320	2.40	79.6262	6.6	12 523	12.0	248 832	20.8	3 893 289
.25	.000977	2.45	88.2735	6.7	13 501	12.2	270 271	21.0	4 084 101
.30	.002430	2.50	97.6562	6.8	14 539	12.4	293 163	21.2	4 282 322
.35	.005252	2.55	107.820	6.9	15 640	12.6	317 580	21.4	4 488 166
.40	.010240	2.60	118.814	7.0	16 807	12.8	343 597	21.6	4 701 850
.45	.018453	2.70	143.489	7.1	18 042	13.0	371 293	21.8	4 923 597
.50	.031250	2.80	172.104	7.2	19 349	13.2	400 746	22.0	5 153 632
.55	.050328	2.90	205.111	7.3	20 731	13.4	432 040	22.2	5 392 186
.60	.077760	3.00	243.000	7.4	22 190	13.6	465 259	22.4	5 639 493
.65	.116029	3.10	286.292	7.5	23 730	13.8	500 490	22.6	5 895 793
.70	.168070	3.20	335.544	7.6	25 355	14.0	537 824	22.8	6 161 327
.75	.237305	3.30	391.354	7.7	27 068	14.2	577 353	23.0	6 436 343
.80	.327680	3.40	454.354	7.8	28 872	14.4	619 174	23.2	6 721 093
.85	.443705	3.50	525.219	7.9	30 771	14.6	663 383	23.4	7 015 834
.90	.590490	3.60	604.662	8.0	32 768	14.8	710 082	23.6	7 320 825
.95	.773781	3.70	693.440	8.1	34 868	15.0	759 375	23.8	7 636 332
1.00	1.00000	3.80	792.352	8.2	37 074	15.2	811 368	24.0	7 962 624
1.05	1.27628	3.90	902.242	8.3	39 390	15.4	866 171	24.2	8 299 976
1.10	1.61051	4.00	1024.00	8.4	41 821	15.6	923 896	24.4	8 648 666
1.15	2.01135	4.10	1158.56	8.5	44 371	15.8	984 658	24.6	9 008 978
1.20	2.48832	4.20	1306.91	8.6	47 043	16.0	1 048 576	24.8	9 381 200
1.25	3.05176	4.30	1470.08	8.7	49 842	16.2	1 115 771	25.0	9 765 625
1.30	3.71293	4.40	1649.16	8.8	52 773	16.4	1 186 367	25.2	10 162 550
1.35	4.48403	4.50	1845.28	8.9	55 841	16.6	1 260 493	25.4	10 572 278
1.40	5.37824	4.60	2059.63	9.0	59 049	16.8	1 338 278	25.6	10 995 116
1.45	6.40973	4.70	2293.45	9.1	62 403	17.0	1 419 857	25.8	11 431 377
1.50	7.59375	4.80	2548.04	9.2	65 908	17.2	1 505 366	26.0	11 881 376
1.55	8.94661	4.90	2824.75	9.3	69 569	17.4	1 594 947	26.2	12 345 437
1.60	10.4858	5.00	3125.00	9.4	73 390	17.6	1 688 742	26.4	12 823 886
1.65	12.2298	5.10	3450.25	9.5	77 378	17.8	1 786 899	26.6	13 317 055
1.70	14.1986	5.20	3802.04	9.6	81 537	18.0	1 889 568	26.8	13 825 281
1.75	16.4131	5.30	4181.95	9.7	85 873	18.2	1 996 903	27.0	14 348 907
1.80	18.8957	5.40	4591.65	9.8	90 392	18.4	2 109 061	27.2	14 888 280
1.85	21.6700	5.50	5032.84	9.9	95 099	18.6	2 226 203	27.4	15 443 752
1.90	24.7610	5.60	5507.32	10.0	100 000	18.8	2 348 493	27.6	16 015 681
1.95	28.1951	5.70	6016.92	10.2	110 408	19.0	2 476 099	27.8	16 604 430
2.00	32.0000	5.80	6563.57	10.4	121 665	19.2	2 609 193	28.0	17 210 368
2.05	36.2051	5.90	7149.24	10.6	133 823	19.4	2 747 949	28.2	17 833 868
2.10	40.8410	6.00	7776.00	10.8	146 933	19.6	2 892 547	28.4	18 475 309
2.15	45.9401	6.10	8445.96	11.0	161 051	19.8	3 043 168	28.6	19 135 075
2.20	51.5363	6.20	9161.33	11.2	176 234	20.0	3 200 000	28.8	19 813 557
2.25	57.6650	6.30	9924.37	11.4	192 541	20.2	3 363 232	29.0	20 511 149

Fifth Roots and Fifth Powers (Concluded)

Number or root	Power	Number or root	Power	Number or root	Power	Number or root	Power
29.2	21 228 253	38.5	84 587 005	58	656 356 768	79	3 077 056 399
29.4	21 965 275	39.0	90 224 199	59	714 924 299	80	3 276 800 000
29.6	22 722 628	39.5	96 158 012	60	777 600 000	81	3 486 784 401
29.8	23 500 728	40	102 400 000	61	844 596 301	82	3 707 398 432
30.0	24 300 000	41	115 856 201	62	916 132 832	83	3 939 040 643
30.5	26 393 634	42	130 691 232	63	992 436 543	84	4 182 119 424
31.0	28 629 151	43	147 008 443	64	1 073 741 824	85	4 437 053 125
31.5	31 013 642	44	164 916 224	65	1 160 290 625	86	4 704 270 176
32.0	33 554 432	45	184 528 125	66	1 252 332 576	87	4 984 209 207
32.5	36 259 082	46	205 962 976	67	1 350 125 107	88	5 277 319 168
33.0	39 135 393	47	229 345 007	68	1 453 933 568	89	5 584 059 449
33.5	42 191 410	48	254 803 968	69	1 564 031 349	90	5 904 900 000
34.0	45 435 424	49	282 475 249	70	1 680 700 000	91	6 240 321 451
34.5	48 875 980	50	312 500 000	71	1 804 229 351	92	6 590 815 232
35.0	52 521 875	51	345 025 251	72	1 934 917 632	93	6 956 883 693
35.5	56 382 167	52	380 204 032	73	2 073 071 593	94	7 339 040 224
36.0	60 466 176	53	418 195 493	74	2 219 006 624	95	7 737 809 375
36.5	64 783 487	54	459 165 024	75	2 373 046 875	96	8 153 726 976
37.0	69 343 957	55	503 284 375	76	2 535 525 376	97	8 587 340 257
37.5	74 157 715	56	550 731 776	77	2 706 784 157	98	9 039 207 968
38.0	79 235 168	57	601 692 057	78	2 887 174 368	99	9 509 900 499

Decimals of a Foot for Each 1/64th of an Inch

Inch	0 inch	1 inch	2 inches	3 inches	4 inches	5 inches	6 inches	7 inches	8 inches	9 inches	10 inches	11 inches
0	0	.0833	.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167
1/64	.0013	.0846	.1680	.2513	.3346	.4180	.5013	.5846	.6680	.7513	.8346	.9180
1/32	.0026	.0859	.1693	.2526	.3359	.4193	.5026	.5859	.6693	.7526	.8359	.9193
3/64	.0039	.0872	.1706	.2539	.3372	.4206	.5039	.5872	.6706	.7539	.8372	.9206
1/16	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
5/64	.0065	.0898	.1732	.2565	.3398	4232	.5065	.5898	.6732	.7565	8398	.9232
3/32	.0078	.0911	.1745	.2578	.3411	.4245	.5078	.5911	.6745	.7578	.8411	.9245
7/64	.0091	.0924	.1758	.2591	.3424	.4258	.5091	.5924	.6758	.7591	.8424	.9258
1/8	.0104	.0937	.1771	.2604	.3437	.4271	.5104	.5937	.6771	.7604	.8437	.9271
9/64	.0117	.0951	.1784	.2617	.3451	.4284	.5117	.5951	.6784	.7617	.8451	.9284
5/32	.0130	.0964	.1797	.2630	.3464	.4297	.5130	.5964	.6797	.7630	.8464	.9297
11/64	.0143	.0977	.1810	.2643	.3477	.4310	.5143	.5977	.6810	.7643	.8477	.9310
3/16	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323
13/64	.0169	.1003	.1836	.2669	.3503	.4336	.5169	.6003	.6836	.7669	.8503	.9336
7/32	.0182	.1016	.1849	.2682	3516	.4349	.5182	.6016	.6849	.7682	.8516	.9349
15/64	.0195	.1029	.1862	.2695	.3529	.4362	.5195	.6029	.6862	.7695	.8529	.9362
1/4	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
17/64	.0221	.1055	.1888	.2721	.3555	.4388	.5221	.6055	.6888	.7721	.8555	.9388
9/32	.0234	.1068	.1901	.2734	.3568	.4401	.5234	.6068	.6901	.7734	.8568	.9401

Decimals of a Foot for Each 1/64th of an Inch (Concluded)

Inch	0 inch	1 inch	2 inches	3 inches	4 inches	5 inches	6 inches	7 inches	8 inches	9 inches	10 inches	11 inches
19/64	.0247	.1081	.1914	.2747	.3581	.4414	.5247	.6081	.6914	.7747	.8581	.9414
5/16	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
21/64	.0273	.1107	.1940	.2773	.3607	.4440	.5273	.6107	.6940	.7773	.8607	.9440
11/32	.0286	.1120	.1953	.2786	.3620	.4453	.5286	.6120	.6953	.7786	.8620	.9453
23/64	.0299	.1133	.1966	.2799	.3633	.4466	.5299	.6133	.6966	.7799	.8633	.9466
3/8	.0312	.1146	.1979	.2812	.3646	.4479	.5312	.6146	.6979	.7812	.8646	.9479
25/64	.0326	.1159	.1992	.2826	.3659	.4492	.5326	.6159	.6992	.7826	.8659	.9492
13/32	.0339	.1172	.2005	.2839	.3672	.4505	.5339	.6172	.7005	.7839	.8672	.9505
27/64	.0352	.1185	.2018	.2852	.3685	.4518	.5352	.6185	.7018	.7852	.8685	.9518
7/16	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531
29/64	.0378	.1211	.2044	.2878	.3711	.4544	.5378	.6211	.7044	.7878	.8711	.9544
15/32	.0391	.1224	.2057	.2891	.3724	.4557	.5391	.6224	.7057	.7891	.8724	.9557
31/64	.0404	.1237	.2070	.2904	.3737	.4570	.5404	.6237	.7070	.7904	.8737	.9570
1/2	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
33/64	.0430	.1263	.2096	.2930	.3763	.4596	.5430	.6263	.7096	.7930	.8763	.9596
17/32	.0443	.1276	.2109	.2943	.3776	.4609	.5443	.6276	.7109	.7943	.8776	.9609
35/64	.0456	.1289	.2122	.2956	.3789	.4622	.5456	.6289	.7122	.7956	.8789	.9622
9/16	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635
37/64	.0482	.1315	.2148	.2982	.3815	.4648	.5482	.6315	.7148	.7982	.8815	.9648
19/32	.0495	.1328	.2161	.2995	.3828	.4661	.5495	.6328	.7161	.7995	.8828	.9661
39/64	.0508	.1341	.2174	.3008	.3841	.4674	.5508	.6341	.7174	.8008	.8841	.9674
5/8	.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688
41/64	.0534	.1367	.2201	.3034	.3867	.4701	.5534	.6367	.7201	.8034	.8867	.9701
21/32	.0547	.1380	.2214	.3047	.3880	.4714	.5547	.6380	.7214	.8047	.8880	.9714
43/64	.0560	.1393	.2227	.3060	.3893	.4727	.5560	.6393	.7227	.8060	.8893	.9727
11/16	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
45/64	.0586	.1419	.2253	.3086	.3919	.4753	.5586	.6419	.7253	.8086	.8919	.9753
23/32	.0599	.1432	.2266	.3099	.3932	.4766	.5599	.6432	.7266	.8099	.8932	.9766
47/64	.0612	.1445	.2279	.3112	.3945	.4779	.5612	.6445	.7279	.8112	.8945	.9779
3/4	.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	.9792
49/64	.0638	.1471	.2305	.3138	.3971	.4805	.5638	.6471	.7305	.8138	.8971	.9805
25/32	.0651	.1484	.2318	.3151	.3984	.4818	.5651	.6484	.7318	.8151	.8984	.9818
51/64	.0664	.1497	.2331	.3164	.3997	.4831	.5664	.6497	.7331	.8164	.8997	.9831
13/16	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844
53/64	.0690	.1523	.2357	.3190	.4023	.4857	.5690	.6523	.7357	.8190	.9023	.9857
27/32	.0703	.1536	.2370	.3203	.4036	.4870	.5703	.6536	.7370	.8203	.9036	.9870
55/64	.0716	.1549	.2383	.3216	.4049	.4883	.5716	.6549	.7383	.8216	.9049	.9883
7/8	.0729	.1562	.2396	.3229	.4062	.4896	.5729	.6562	.7396	.8229	.9062	.9896
57/64	.0742	.1576	.2409	.3242	.4076	.4909	.5742	.6576	.7409	.8242	.9076	.9909
29/32	.0755	.1589	.2422	.3255	.4089	.4922	.5755	.6589	.7422	.8255	.9089	.9922
59/64	.0768	.1602	.2435	.3268	.4102	.4935	.5768	.6602	.7435	.8268	.9102	.9935
15/16	.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948
61/64	.0794	.1628	.2461	.3294	.4128	.4961	.5794	.6628	.7461	.8294	.9128	.9961
31/32	.0807	.1641	.2474	.3307	.4141	.4974	.5807	.6641	.7474	.8307	.9141	.9974
63/64	.0820	.1654	.2487	.3320	.4154	.4987	.5820	.6654	.7487	.8320	.9154	.9987
1	....	....	....	....	....	....	....	....	....	....	....	1.0000

Decimals of an Inch for Each 1/64th

1/32	1/64	Decimal	Fraction	1/32	1/64	Decimal	Fraction
	1	.015625			33	.515625	
1	2	.03125		17	34	.53125	
	3	.046875			35	.546875	
2	4	.0625	1/16	18	36	.5625	9/16
	5	.078125			37	.578125	
3	6	.09375		19	38	.59375	
	7	.109375			39	.609375	
4	8	.125	1/8	20	40	.625	5/8
	9	.140625			41	.640625	
5	10	.15625		21	42	.65625	
	11	.171875			43	.671875	
6	12	.1875	3/16	22	44	.6875	11/16
	13	.203125			45	.703125	
7	14	.21875		23	46	.71875	
	15	.234375			47	.734375	
8	16	.25	1/4	24	48	.75	3/4
	17	.265625			49	.765625	
9	18	.28125		25	50	.78125	
	19	.296875			51	.796875	
10	20	.3125	5/16	26	52	.8125	13/16
	21	.328125			53	.828125	
11	22	.34375		27	54	.84375	
	23	.359375			55	.859375	
12	24	.375	3/8	28	56	.875	7/8
	25	.390625			57	.890625	
13	26	.40625		29	58	.90625	
	27	.421875			59	.921875	
14	28	.4375	7/16	30	60	.9375	15/16
	29	.453125			61	.953125	
15	30	.46875		31	62	.96875	
	31	.484375			63	.984375	
16	32	.5	1/2	32	64	1	1

Wire and Sheet Metal Gages in Approximate Decimals of an Inch

(Adopted by the Association of American Steel Manufacturers, Dec. 10, 1908.)

Gage numbers	United States	American or Brown & Sharpe	Washburn & Moen, Am. Steel and Wire Co., Roebling	Trenton Iron Co.	Birmingham or Stubs' iron-wire	Stubs' steel wire	British Imperial	Gage numbers
7-0	.500	....	....	....	....	....	.500	7-0
6-0	.469	....	.460	....	....	....	.464	6-0
5-0	.438	....	.430	.450	....	....	.432	5-0
4-0	.406	.460	.394	.400	.454	....	.400	4-0
000	.375	.410	.363	.360	.425	....	.372	000
00	.344	.365	.331	.330	.380	....	.348	00
0	.313	.325	.307	.305	.340	....	.324	0
1	.281	.289	.283	.285	.300	.227	.300	1
2	.266	.258	.263	.265	.284	.219	.276	2
3	.250	.229	.244	.245	.259	.212	.252	3
4	.234	.204	.225	.225	.238	.207	.232	4
5	.219	.182	.207	.205	.220	.204	.212	5
6	.203	.162	.192	.190	.203	.201	.192	6
7	.188	.144	.177	.175	.180	.199	.176	7
8	.172	.128	.162	.160	.165	.197	.160	8
9	.156	.114	.148	.145	.148	.194	.144	9
10	.141	.102	.135	.130	.134	.191	.128	10
11	.125	.0907	.121	.118	.120	.188	.116	11
12	.109	.0808	.106	.105	.109	.185	.104	12
13	.0938	.072	.0915	.0925	.095	.182	.092	13
14	.0781	.0641	.080	.0806	.083	.180	.080	14
15	.0703	.0571	.072	.070	.072	.178	.072	15
16	.0625	.0508	.0625	.061	.065	.175	.064	16
17	.0563	.0453	.054	.0525	.058	.172	.056	17
18	.050	.0403	.0475	.045	.049	.168	.048	18
19	.0438	.0359	.041	.040	.042	.164	.040	19
20	.0375	.032	.0348	.035	.035	.161	.036	20
21	.0344	.0285	.0318	.031	.032	.157	.032	21
22	.0313	.0253	.0286	.028	.028	.155	.028	22
23	.0281	.0226	.0258	.025	.025	.153	.024	23
24	.025	.0201	.023	.0225	.022	.151	.022	24
25	.0219	.0179	.0204	.020	.020	.148	.020	25
26	.0188	.0159	.0181	.018	.018	.146	.018	26
27	.0172	.0142	.0173	.017	.016	.143	.0164	27
28	.0156	.0126	.0162	.016	.014	.139	.0149	28
29	.0141	.0113	.015	.015	.013	.134	.0136	29
30	.0125	.010	.014	.014	.012	.127	.0124	30
31	.0109	.0089	.0132	.013	.010	.120	.0116	31
32	.0102	.008	.0128	.012	.009	.115	.0108	32
33	.0094	.0071	.0118	.011	.008	.112	.010	33
34	.0086	.0063	.0104	.010	.007	.110	.0092	34
35	.0078	.0056	.0095	.0095	.005	.108	.0084	35
36	.007	.005	.009	.009	.004	.106	.0076	36
37	.0066	.0045	.0085	.0085	....	.103	.0068	37
38	.0063	.004	.008	.008	....	.101	.006	38
39	....	.0035	.0075	.0075	....	.099	.0052	39
40	....	.0031	.007	.007	....	.097	.0048	40

PROPORTIONS OF SCREW THREADS NUTS AND BOLT HEADS

(Recommended by the Franklin Institute.)

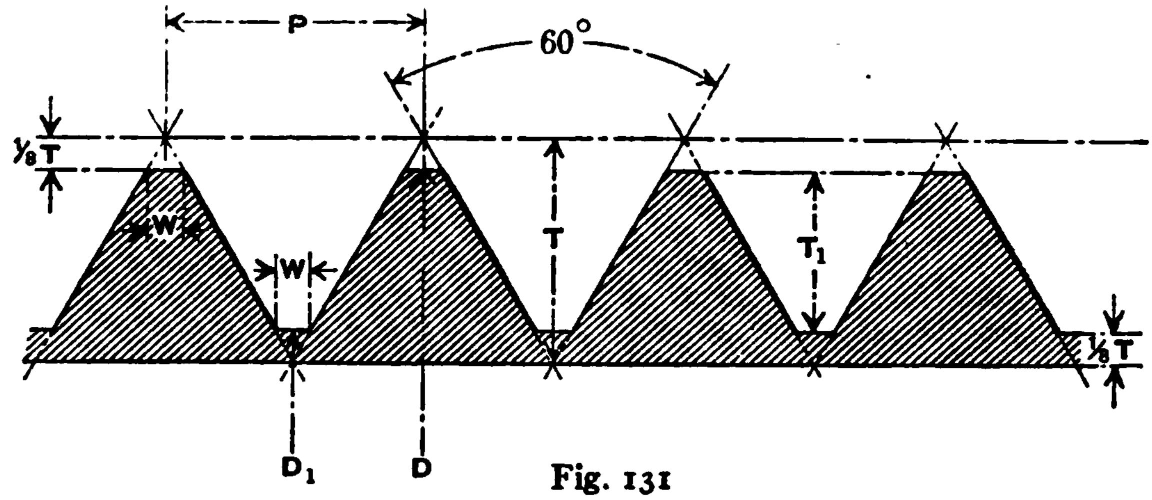


Fig. 131

Screw Threads.

D = diameter of bolt,
D_1 = diameter at root of thread,
P = pitch,
N = number of threads per inch,
W = width of flat, top or bottom of each thread,
T = depth of V,
T_1 = depth of thread.

$$P = \frac{1}{N}. \qquad T = \cos 30^\circ P = .866\,P.$$

$$N = \frac{1}{P}. \qquad T_1 = \frac{3}{4}T = .65\,P.$$

$$W = \frac{P}{8}. \qquad D_1 = D - 2\,T_1 = D - 1.299\,P.$$

$$D = D_1 + 2 \times 0.866 \times 0.75\,P = D_1 + 1.299\,P.$$

Square and Hexagon Heads and Nuts. Short diameter of rough nut = 1½ × diameter of bolt + ⅛ inch.

Short diameter of finished nut = 1½ × diameter of bolt + 1/16 inch.

Thickness of rough nut = diameter of bolt.

Thickness of finished nut = diameter of bolt − 1/16 inch.

Short diameter of rough head = 1½ × diameter of bolt + ⅛ inch.

Short diameter of finished head = 1½ × diameter of bolt + 1/16 inch.

Thickness of rough head = ½ of short diameter of head.

Thickness of finished head = diameter of bolt − 1/16 inch.

The long diameter of a hexagon nut may be obtained by multiplying the short diameter by 1.155 and the long diameter of a square nut by multiplying the short diameter by 1.414.

In 1864, a committee of the Franklin Institute recommended the above system of screw threads and bolts, which was devised by Mr. William Sellers of Philadelphia. This system, as far as it relates to screw threads, is generally used in the United States, but the proportions of bolt heads and nuts have not been generally accepted because the sizes of bar required to make the nuts are special, and extra work is necessary to make the bolt heads. Under the name of United States Standard, the U. S. Navy Department in 1868 adopted the Sellers System, except for finished heads and nuts, which it made the same as for rough heads and nuts.

Dimensions of Screw Threads, Nuts and Bolt Heads

(Recommended by the Franklin Institute.)

Bolts and threads

Diameter	Threads per inch	Width of flats of threads	Diameter at root of threads	Area at root of threads	Area of body	Tensile strength — Bottom of thread — At 10 000 pounds per square inch	At 12 500 pounds per square inch	At 17 500 pounds per square inch
Inches		Inch	Inches	Square inches	Square inches	Pounds	Pounds	Pounds
1/4	20	.0063	.185	.027	.049	269	336	471
5/16	18	.0069	.240	.045	.077	454	568	795
3/8	16	.0078	.294	.068	.110	678	848	1 187
7/16	14	.0089	.345	.093	.150	933	1 166	1 633
1/2	13	.0096	.400	.126	.196	1 257	1 571	2 200
9/16	12	.0104	.454	.162	.249	1 621	2 026	2 837
5/8	11	.0114	.507	.202	.307	2 018	2 523	3 532
3/4	10	.0125	.620	.302	.442	3 020	3 775	5 285
7/8	9	.0139	.731	.419	.601	4 193	5 241	7 338
1	8	.0156	.838	.551	.785	5 510	6 888	9 643
1 1/8	7	.0179	.939	.693	.994	6 931	8 664	12 129
1 1/4	7	.0179	1.064	.890	1.227	8 899	11 124	15 573
1 3/8	6	.0208	1.158	1.054	1.485	10 541	13 176	18 447
1 1/2	6	.0208	1.283	1.294	1.767	12 938	16 173	22 642
1 5/8	5 1/2	.0227	1.389	1.514	2.074	15 149	18 936	26 511
1 3/4	5	.0250	1.490	1.744	2.405	17 441	21 801	30 522
1 7/8	5	.0250	1.615	2.048	2.761	20 490	25 613	35 858
2	4 1/2	.0278	1.711	2.300	3.142	23 001	28 751	40 252
2 1/4	4 1/2	.0278	1.961	3.021	3.976	30 213	37 766	52 873
2 1/2	4	.0313	2.175	3.715	4.909	37 163	46 454	65 035
2 3/4	4	.0313	2.425	4.619	5.940	46 196	57 745	80 843
3	3 1/2	.0357	2.629	5.427	7.069	54 277	67 846	94 985
3 1/4	3 1/2	.0357	2.879	6.508	8.296	65 092	81 365	113 911
3 1/2	3 1/4	.0385	3.100	7.548	9.621	75 491	94 364	132 109
3 3/4	3	.0417	3.317	8.640	11.045	86 412	108 015	151 221
4	3	.0417	3.567	9.991	12.566	99 929	124 911	174 876
4 1/4	2 7/8	.0435	3.798	11.328	14.186	113 302	141 628	198 279
4 1/2	2 3/4	.0455	4.027	12.738	15.904	127 405	159 256	222 959
4 3/4	2 5/8	.0476	4.255	14.218	17.721	142 205	177 756	248 859
5	2 1/2	.0500	4.480	15.763	19.635	157 659	197 074	275 903
5 1/4	2 1/2	.0500	4.730	17.572	21.648	175 745	219 681	307 554
5 1/2	2 3/8	.0526	4.953	19.265	23.758	192 678	240 848	337 187
5 3/4	2 3/8	.0526	5.203	21.259	25.967	212 620	265 775	372 085
6	2 1/4	.0556	5.422	23.091	28.274	230 947	288 684	404 157

Dimensions of Screw Threads, Nuts and Bolt Heads (Concluded)

(Recommended by the Franklin Institute.)

Bolts and threads					Rough nuts and heads				
Diameter	Shearing strength				Short diameter of square and hexagon	Long diameter of square	Long diameter of hexagon	Thickness of nuts	Thickness of heads
	Full bolt		Bottom of thread						
	At 7500 pounds per square inch	At 10 000 pounds per square inch	At 7500 pounds per square inch	At 10 000 pounds per square inch					
In.	Pounds	Pounds	Pounds	Pounds	In.	In.	In.	In.	In.
1/4	368	491	202	269	1/2	.707	.578	1/4	1/4
5/16	575	767	341	454	19/32	.840	.686	5/16	19/64
3/8	828	1 104	509	678	11/16	.972	.794	3/8	11/32
7/16	1 127	1 503	700	933	25/32	1.105	.902	7/16	25/64
1/2	1 472	1 963	943	1 257	7/8	1.237	1.011	1/2	7/16
9/16	1 864	2 485	1 216	1 621	31/32	1.370	1.119	9/16	31/64
5/8	2 301	3 068	1 514	2 018	1 1/16	1.502	1.227	5/8	17/32
3/4	3 314	4 418	2 265	3 020	1 1/4	1.768	1.444	3/4	5/8
7/8	4 510	6 013	3 145	4 193	1 7/16	2.033	1.660	7/8	23/32
1	5 891	7 854	4 133	5 510	1 5/8	2.298	1.877	1	13/16
1 1/8	7 455	9 940	5 198	6 931	1 13/16	2.563	2.093	1 1/8	29/32
1 1/4	9 204	12 272	6 674	8 899	2	2.828	2.310	1 1/4	1
1 3/8	11 137	14 849	7 906	10 541	2 3/16	3.093	2.527	1 3/8	1 3/32
1 1/2	13 253	17 671	9 704	12 938	2 3/8	3.358	2.743	1 1/2	1 3/16
1 5/8	15 554	20 739	11 362	15 149	2 9/16	3.623	2.960	1 5/8	1 9/32
1 3/4	18 040	24 053	13 081	17 441	2 3/4	3.889	3.176	1 3/4	1 3/8
1 7/8	20 709	27 612	15 368	20 490	2 15/16	4.154	3.393	1 7/8	1 15/32
2	23 562	31 416	17 251	23 001	3 1/8	4.419	3.609	2	1 9/16
2 1/4	29 821	39 761	22 660	30 213	3 1/2	4.949	4.043	2 1/4	1 3/4
2 1/2	36 815	49 087	27 872	37 163	3 7/8	5.479	4.476	2 1/2	1 15/16
2 3/4	44 547	59 396	34 647	46 196	4 1/4	6.010	4.909	2 3/4	2 1/8
3	53 015	70 686	40 708	54 277	4 5/8	6.540	5.342	3	2 5/16
3 1/4	62 219	82 958	48 819	65 092	5	7.070	5.775	3 1/4	2 1/2
3 1/2	72 158	96 211	56 618	75 491	5 3/8	7.600	6.208	3 1/2	2 11/16
3 3/4	82 835	110 447	64 809	86 412	5 3/4	8.131	6.641	3 3/4	2 7/8
4	94 248	125 664	74 947	99 929	6 1/8	8.661	7.074	4	3 1/16
4 1/4	106 397	141 863	84 977	113 302	6 1/2	9.191	7.508	4 1/4	3 1/4
4 1/2	119 282	159 043	95 554	127 405	6 7/8	9.721	7.941	4 1/2	3 7/16
4 3/4	132 904	177 205	106 654	142 205	7 1/4	10.252	8.374	4 3/4	3 5/8
5	147 263	196 350	118 244	157 659	7 5/8	10.782	8.807	5	3 13/16
5 1/4	162 356	216 475	131 809	175 745	8	11.312	9.240	5 1/4	4
5 1/2	178 187	237 583	144 509	192 678	8 3/8	11.842	9.673	5 1/2	4 3/16
5 3/4	194 754	259 672	159 465	212 620	8 3/4	12.373	10.106	5 3/4	4 3/8
6	212 057	282 743	173 210	230 947	9 1/8	12.903	10.539	6	4 9/16

AREA FACTORS FOR TUBES

Explanation of Table

This table of area factors may be used to calculate the sectional area of tubes of any diameter and any wall thickness, both being expressed to the nearest one thousandth of an inch. To apply the table, use the following

Rule. Subtract the thickness of the tube wall from the outside diameter, both expressed in inches and decimals; then multiply this remainder by the tabular area factor corresponding to the given thickness. The result will be the sectional area of the tube in square inches.

Example. Find the sectional area of a tube whose outside diameter is 8⅝ inches and thickness of wall 0.284 inch.

Solution. Outside diameter less thickness = 8.625 − 0.284 = 8.341.

Tabular area factor corresponding to the given thickness, 0.284 inch, is 0.8922, which is found in the column headed .004 and opposite .28 in column one.

The required area is

$$8.341 \times .8922 = 7.442 \text{ square inches.}$$

Note. When the thickness of wall exceeds one inch, add to the tabular area factor corresponding to the decimal part of the thickness, one, two, or three, etc., times the factor corresponding to 1.000 inch, as the case may be, thus:

Area factor for thickness of 1.625 inch will be

Area factor for .625 = 1.9635
Area factor for 1.000 = 3.1416

Area factor for 1.625 = 5.1051

In like manner the area factor corresponding to a thickness of 2.625 inches will be 1.9635 + (2 × 3.1416) = 8.2467.

Basis of Table. This table was calculated by means of the formula

$$A = \pi t(D - t),$$

where A = sectional area in square inches;
D = outside diameter in inches;
t = thickness of wall in inches.

Thickness in inches	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
.00	.....	.0031	.0063	.0094	.0126	.0157	.0188	.0220	.0251	.0283
.01	.0314	.0346	.0377	.0408	.0440	.0471	.0503	.0534	.0565	.0597
.02	.0628	.0660	.0691	.0723	.0754	.0785	.0817	.0848	.0880	.0911
.03	.0942	.0974	.1005	.1037	.1068	.1100	.1131	.1162	.1194	.1225
.04	.1257	.1288	.1319	.1351	.1382	.1414	.1445	.1477	.1508	.1539
.05	.1571	.1602	.1634	.1665	.1696	.1728	.1759	.1791	.1822	.1854
.06	.1885	.1916	.1948	.1979	.2011	.2042	.2073	.2105	.2136	.2168
.07	.2199	.2231	.2262	.2293	.2325	.2356	.2388	.2419	.2450	.2482
.08	.2513	.2545	.2576	.2608	.2639	.2670	.2702	.2733	.2765	.2796
.09	.2827	.2859	.2890	.2922	.2953	.2985	.3016	.3047	.3079	.3110
.10	.3142	.3173	.3204	.3236	.3267	.3299	.3330	.3362	.3393	.3424
.11	.3456	.3487	.3519	.3550	.3581	.3613	.3644	.3676	.3707	.3738
.12	.3770	.3801	.3833	.3864	.3896	.3927	.3958	.3990	.4021	.4053
.13	.4084	.4115	.4147	.4178	.4210	.4241	.4273	.4304	.4335	.4367
.14	.4398	.4430	.4461	.4492	.4524	.4555	.4587	.4618	.4650	.4681
.15	.4712	.4744	.4775	.4807	.4838	.4869	.4901	.4932	.4964	.4995

Area Factors for Tubes (Continued)

Thickness in inches	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
.15	.4712	.4744	.4775	.4807	.4838	.4869	.4901	.4932	.4964	.4995
.16	.5027	.5058	.5089	.5121	.5152	.5184	.5215	.5246	.5278	.5309
.17	.5341	.5372	.5404	.5435	.5466	.5498	.5529	.5561	.5592	.5623
.18	.5655	.5686	.5718	.5749	.5781	.5812	.5843	.5875	.5906	.5938
.19	.5969	.6000	.6032	.6063	.6095	.6126	.6158	.6189	.6220	.6252
.20	.6283	.6315	.6346	.6377	.6409	.6440	.6472	.6503	.6535	.6566
.21	.6597	.6629	.6660	.6692	.6723	.6754	.6786	.6817	.6849	.6880
.22	.6912	.6943	.6974	.7006	.7037	.7069	.7100	.7131	.7163	.7194
.23	.7226	.7257	.7288	.7320	.7351	.7383	.7414	.7446	.7477	.7508
.24	.7540	.7571	.7603	.7634	.7665	.7697	.7728	.7760	.7791	.7823
.25	.7854	.7885	.7917	.7948	.7980	.8011	.8042	.8074	.8105	.8137
.26	.8168	.8200	.8231	.8262	.8294	.8325	.8357	.8388	.8419	.8451
.27	.8482	.8514	.8545	.8577	.8608	.8639	.8671	.8702	.8734	.8765
.28	.8796	.8828	.8859	.8891	.8922	.8954	.8985	.9016	.9048	.9079
.29	.9111	.9142	.9173	.9205	.9236	.9268	.9299	.9331	.9362	.9393
.30	.9425	.9456	.9488	.9519	.9550	.9582	.9613	.9645	.9676	.9708
.31	.9739	.9770	.9802	.9833	.9865	.9896	.9927	.9959	.9990	1.0022
.32	1.0053	1.0085	1.0116	1.0147	1.0179	1.0210	1.0242	1.0273	1.0304	1.0336
.33	1.0367	1.0399	1.0430	1.0462	1.0493	1.0524	1.0556	1.0587	1.0619	1.0650
.34	1.0681	1.0713	1.0744	1.0776	1.0807	1.0838	1.0870	1.0901	1.0933	1.0964
.35	1.0996	1.1027	1.1058	1.1090	1.1121	1.1153	1.1184	1.1215	1.1247	1.1278
.36	1.1310	1.1341	1.1373	1.1404	1.1435	1.1467	1.1498	1.1530	1.1561	1.1592
.37	1.1624	1.1655	1.1687	1.1718	1.1750	1.1781	1.1812	1.1844	1.1875	1.1907
.38	1.1938	1.1969	1.2001	1.2032	1.2064	1.2095	1.2127	1.2158	1.2189	1.2221
.39	1.2252	1.2284	1.2315	1.2346	1.2378	1.2409	1.2441	1.2472	1.2504	1.2535
.40	1.2566	1.2598	1.2629	1.2661	1.2692	1.2723	1.2755	1.2786	1.2818	1.2849
.41	1.2881	1.2912	1.2943	1.2975	1.3006	1.3038	1.3069	1.3100	1.3132	1.3163
.42	1.3195	1.3226	1.3258	1.3289	1.3320	1.3352	1.3383	1.3415	1.3446	1.3477
.43	1.3509	1.3540	1.3572	1.3603	1.3635	1.3666	1.3697	1.3729	1.3760	1.3792
.44	1.3823	1.3854	1.3886	1.3917	1.3949	1.3980	1.4012	1.4043	1.4074	1.4106
.45	1.4137	1.4169	1.4200	1.4231	1.4263	1.4294	1.4326	1.4357	1.4388	1.4420
.46	1.4451	1.4483	1.4514	1.4546	1.4577	1.4608	1.4640	1.4671	1.4703	1.4734
.47	1.4765	1.4797	1.4828	1.4860	1.4891	1.4923	1.4954	1.4985	1.5017	1.5048
.48	1.5080	1.5111	1.5142	1.5174	1.5205	1.5237	1.5268	1.5300	1.5331	1.5362
.49	1.5394	1.5425	1.5457	1.5488	1.5519	1.5551	1.5582	1.5614	1.5645	1.5677
.50	1.5708	1.5739	1.5771	1.5802	1.5834	1.5865	1.5896	1.5928	1.5959	1.5991
.51	1.6022	1.6054	1.6085	1.6116	1.6148	1.6179	1.6211	1.6242	1.6273	1.6305
.52	1.6336	1.6368	1.6399	1.6431	1.6462	1.6493	1.6525	1.6556	1.6588	1.6619
.53	1.6650	1.6682	1.6713	1.6745	1.6776	1.6808	1.6839	1.6870	1.6902	1.6933
.54	1.6965	1.6996	1.7027	1.7059	1.7090	1.7122	1.7153	1.7185	1.7216	1.7247
.55	1.7279	1.7310	1.7342	1.7373	1.7404	1.7436	1.7467	1.7499	1.7530	1.7562
.56	1.7593	1.7624	1.7656	1.7687	1.7719	1.7750	1.7781	1.7813	1.7844	1.7876
.57	1.7907	1.7939	1.7970	1.8001	1.8033	1.8064	1.8096	1.8127	1.8158	1.8190
.58	1.8221	1.8253	1.8284	1.8315	1.8347	1.8378	1.8410	1.8441	1.8473	1.8504

Area Factors for Tubes (Concluded)

Thickness in inches	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
.58	1.8221	1.8253	1.8284	1.8315	1.8347	1.8378	1.8410	1.8441	1.8473	1.8504
.59	1.8535	1.8567	1.8598	1.8630	1.8661	1.8692	1.8724	1.8755	1.8787	1.8818
.60	1.8850	1.8881	1.8912	1.8944	1.8975	1.9007	1.9038	1.9069	1.9101	1.9132
.61	1.9164	1.9195	1.9227	1.9258	1.9289	1.9321	1.9352	1.9384	1.9415	1.9446
.62	1.9478	1.9509	1.9541	1.9572	1.9604	1.9635	1.9666	1.9698	1.9729	1.9761
.63	1.9792	1.9823	1.9855	1.9886	1.9918	1.9949	1.9981	2.0012	2.0043	2.0075
.64	2.0106	2.0138	2.0169	2.0200	2.0232	2.0263	2.0295	2.0326	2.0358	2.0389
.65	2.0420	2.0452	2.0483	2.0515	2.0546	2.0577	2.0609	2.0640	2.0672	2.0703
.66	2.0735	2.0766	2.0797	2.0829	2.0860	2.0892	2.0923	2.0954	2.0986	2.1017
.67	2.1049	2.1080	2.1112	2.1143	2.1174	2.1206	2.1237	2.1269	2.1300	2.1331
.68	2.1363	2.1394	2.1426	2.1457	2.1489	2.1520	2.1551	2.1583	2.1614	2.1646
.69	2.1677	2.1708	2.1740	2.1771	2.1803	2.1834	2.1865	2.1897	2.1928	2.1960
.70	2.1991	2.2023	2.2054	2.2085	2.2117	2.2148	2.2180	2.2211	2.2242	2.2274
.71	2.2305	2.2337	2.2368	2.2400	2.2431	2.2462	2.2494	2.2525	2.2557	2.2588
.72	2.2619	2.2651	2.2682	2.2714	2.2745	2.2777	2.2808	2.2839	2.2871	2.2902
.73	2.2934	2.2965	2.2996	2.3028	2.3059	2.3091	2.3122	2.3154	2.3185	2.3216
.74	2.3248	2.3279	2.3311	2.3342	2.3373	2.3405	2.3436	2.3468	2.3499	2.3531
.75	2.3562	2.3593	2.3625	2.3656	2.3688	2.3719	2.3750	2.3782	2.3813	2.3845
.76	2.3876	2.3908	2.3939	2.3970	2.4002	2.4033	2.4065	2.4096	2.4127	2.4159
.77	2.4190	2.4222	2.4253	2.4285	2.4316	2.4347	2.4379	2.4410	2.4442	2.4473
.78	2.4504	2.4536	2.4567	2.4599	2.4630	2.4662	2.4693	2.4724	2.4756	2.4787
.79	2.4819	2.4850	2.4881	2.4913	2.4944	2.4976	2.5007	2.5038	2.5070	2.5101
.80	2.5133	2.5164	2.5196	2.5227	2.5258	2.5290	2.5321	2.5353	2.5384	2.5415
.81	2.5447	2.5478	2.5510	2.5541	2.5573	2.5604	2.5635	2.5667	2.5698	2.5730
.82	2.5761	2.5792	2.5824	2.5855	2.5887	2.5918	2.5950	2.5981	2.6012	2.6044
.83	2.6075	2.6107	2.6138	2.6169	2.6201	2.6232	2.6264	2.6295	2.6327	2.6358
.84	2.6389	2.6421	2.6452	2.6484	2.6515	2.6546	2.6578	2.6609	2.6641	2.6672
.85	2.6704	2.6735	2.6766	2.6798	2.6829	2.6861	2.6892	2.6923	2.6955	2.6986
.86	2.7018	2.7049	2.7081	2.7112	2.7143	2.7175	2.7206	2.7238	2.7269	2.7300
.87	2.7332	2.7363	2.7395	2.7426	2.7458	2.7489	2.7520	2.7552	2.7583	2.7615
.88	2.7646	2.7677	2.7709	2.7740	2.7772	2.7803	2.7835	2.7866	2.7897	2.7929
.89	2.7960	2.7992	2.8023	2.8054	2.8086	2.8117	2.8149	2.8180	2.8212	2.8243
.90	2.8274	2.8306	2.8337	2.8369	2.8400	2.8431	2.8463	2.8494	2.8526	2.8557
.91	2.8589	2.8620	2.8651	2.8683	2.8714	2.8746	2.8777	2.8808	2.8840	2.8871
.92	2.8903	2.8934	2.8965	2.8997	2.9028	2.9060	2.9091	2.9123	2.9154	2.9185
.93	2.9217	2.9248	2.9280	2.9311	2.9342	2.9374	2.9405	2.9437	2.9468	2.9500
.94	2.9531	2.9562	2.9594	2.9625	2.9657	2.9688	2.9719	2.9751	2.9782	2.9814
.95	2.9845	2.9877	2.9908	2.9939	2.9971	3.0002	3.0034	3.0065	3.0096	3.0128
.96	3.0159	3.0191	3.0222	3.0254	3.0285	3.0316	3.0348	3.0379	3.0411	3.0442
.97	3.0473	3.0505	3.0536	3.0568	3.0599	3.0631	3.0662	3.0693	3.0725	3.0756
.98	3.0788	3.0819	3.0850	3.0882	3.0913	3.0945	3.0976	3.1008	3.1039	3.1070
.99	3.1102	3.1133	3.1165	3.1196	3.1227	3.1259	3.1290	3.1322	3.1353	3.1385
1.00	3.1416	3.1447	3.1479	3.1510	3.1542	3.1573	3.1604	3.1636	3.1667	3.1699

WEIGHT FACTORS FOR STEEL TUBES

This table of weight factors may be used to calculate the weights per foot length of steel pipe and tubes of any diameter and for any thickness, both being expressed to the nearest one-thousandth inch. To apply the table use the following:

Rule. Subtract the thickness of tube wall from the outside diameter, both being expressed in inches and decimals, then multiply the remainder by the tabular weight factor corresponding to the given thickness. The result will be the weight of tube in pounds per foot length.

Example. Find the weight in pounds per foot of a tube whose outside diameter is 8⅝ inches and thickness of wall 0.284 inch.

Solution. (1) Outside diameter less thickness = 8.625 − 0.284 = 8.341; (2) tabular weight factor corresponding to the given thickness of 0.284 inch is 3.033, which is found in column headed .004 and opposite .28 in column one; (3) the required weight equals 8.341 × 3.033 = 25.30 pounds per foot.

Note. When the thickness of tube wall exceeds one inch, add to the tabular weight factor corresponding to the decimal part of the given thickness, once, twice, thrice, etc., that corresponding to 1.000 inch, as the case may be, thus:

Weight factor for thickness of 1.625 will be

Weight factor for	.625	=	6.675
Weight factor for	1.000	=	10.6802
Weight factor for	1.625	=	17.355

In like manner the weight factor corresponding to a thickness of 2.625 inches will be 6.675 + (2 × 10.6802) = 28.035.

Basis of Table. This table was calculated on an eight-slot Burkhardt machine by means of the formula

$$W = 10.680158\,(D - t)\,t,$$

where W = weight of steel tube in pounds per foot;
D = outside diameter of tube in inches;
t = thickness of tube wall in inches.
Weight one cubic inch steel = 0.2833 pound.

Weight Factors for Steel Tubes, Pounds per Lineal Foot

(Based on weight of one cubic inch of steel equals .2833 pound.)

Thickness in inches	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
.00	......	.011	.021	.032	.043	.053	.064	.075	.085	.096
.01	.107	.117	.128	.139	.150	.160	.171	.182	.192	.203
.02	.214	.224	.235	.246	.256	.267	.278	.288	.299	.310
.03	.320	.331	.342	.352	.363	.374	.384	.395	.406	.417
.04	.427	.438	.449	.459	.470	.481	.491	.502	.513	.523
.05	.534	.545	.555	.566	.577	.587	.598	.609	.619	.630
.06	.641	.651	.662	.673	.684	.694	.705	.716	.726	.737
.07	.748	.758	.769	.780	.790	.801	.812	.822	.833	.844
.08	.854	.865	.876	.886	.897	.908	.918	.929	.940	.951
.09	.961	.972	.983	.993	1.004	1.015	1.025	1.036	1.047	1.057
.10	1.068	1.079	1.089	1.100	1.111	1.121	1.132	1.143	1.153	1.164
.11	1.175	1.185	1.196	1.207	1.218	1.228	1.239	1.250	1.260	1.271
.12	1.282	1.292	1.303	1.314	1.324	1.335	1.346	1.356	1.367	1.378
.13	1.388	1.399	1.410	1.420	1.431	1.442	1.453	1.463	1.474	1.485
.14	1.495	1.506	1.517	1.527	1.538	1.549	1.559	1.570	1.581	1.591
.15	1.602	1.613	1.623	1.634	1.645	1.655	1.666	1.677	1.687	1.698
.16	1.709	1.720	1.730	1.741	1.752	1.762	1.773	1.784	1.794	1.805
.17	1.816	1.826	1.837	1.848	1.858	1.869	1.880	1.890	1.901	1.912
.18	1.922	1.933	1.944	1.954	1.965	1.976	1.987	1.997	2.008	2.019
.19	2.029	2.040	2.051	2.061	2.072	2.083	2.093	2.104	2.115	2.125
.20	2.136	2.147	2.157	2.168	2.179	2.189	2.200	2.211	2.221	2.232
.21	2.243	2.254	2.264	2.275	2.286	2.296	2.307	2.318	2.328	2.339
.22	2.350	2.360	2.371	2.382	2.392	2.403	2.414	2.424	2.435	2.446
.23	2.456	2.467	2.478	2.488	2.499	2.510	2.521	2.531	2.542	2.553
.24	2.563	2.574	2.585	2.595	2.606	2.617	2.627	2.638	2.649	2.659
.25	2.670	2.681	2.691	2.702	2.713	2.723	2.734	2.745	2.755	2.766
.26	2.777	2.788	2.798	2.809	2.820	2.830	2.841	2.852	2.862	2.873
.27	2.884	2.894	2.905	2.916	2.926	2.937	2.948	2.958	2.969	2.980
.28	2.990	3.001	3.012	3.022	3.033	3.044	3.055	3.065	3.076	3.087
.29	3.097	3.108	3.119	3.129	3.140	3.151	3.161	3.172	3.183	3.193
.30	3.204	3.215	3.225	3.236	3.247	3.257	3.268	3.279	3.289	3.300
.31	3.311	3.322	3.332	3.343	3.354	3.364	3.375	3.386	3.396	3.407
.32	3.418	3.428	3.439	3.450	3.460	3.471	3.482	3.492	3.503	3.514
.33	3.524	3.535	3.546	3.556	3.567	3.578	3.589	3.599	3.610	3.621
.34	3.631	3.642	3.653	3.663	3.674	3.685	3.695	3.706	3.717	3.727
.35	3.738	3.749	3.759	3.770	3.781	3.791	3.802	3.813	3.823	3.834
.36	3.845	3.856	3.866	3.877	3.888	3.898	3.909	3.920	3.930	3.941
.37	3.952	3.962	3.973	3.984	3.994	4.005	4.016	4.026	4.037	4.048
.38	4.058	4.069	4.080	4.091	4.101	4.112	4.123	4.133	4.144	4.155
.39	4.165	4.176	4.187	4.197	4.208	4.219	4.229	4.240	4.251	4.261
.40	4.272	4.283	4.293	4.304	4.315	4.325	4.336	4.347	4.358	4.368
.41	4.379	4.390	4.400	4.411	4.422	4.432	4.443	4.454	4.464	4.475
.42	4.486	4.496	4.507	4.518	4.528	4.539	4.550	4.560	4.571	4.582
.43	4.592	4.603	4.614	4.625	4.635	4.646	4.657	4.667	4.678	4.689
.44	4.699	4.710	4.721	4.731	4.742	4.753	4.763	4.774	4.785	4.795
.45	4.806	4.817	4.827	4.838	4.849	4.859	4.870	4.881	4.892	4.902
.46	4.913	4.924	4.934	4.945	4.956	4.966	4.977	4.988	4.998	5.009
.47	5.020	5.030	5.041	5.052	5.062	5.073	5.084	5.094	5.105	5.116
.48	5.126	5.137	5.148	5.159	5.169	5.180	5.191	5.201	5.212	5.223
.49	5.233	5.244	5.255	5.265	5.276	5.287	5.297	5.308	5.319	5.329
.50	5.340	5.351	5.361	5.372	5.383	5.393	5.404	5.415	5.426	5.436

Weight Factors for Steel Tubes, Pounds per Lineal Foot (Concluded)

(Based on weight of one cubic inch of steel equals .2833 pound.)

Thickness in inches	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
.50	5.340	5.351	5.361	5.372	5.383	5.393	5.404	5.415	5.426	5.436
.51	5.447	5.458	5.468	5.479	5.490	5.500	5.511	5.522	5.532	5.543
.52	5.554	5.564	5.575	5.586	5.596	5.607	5.618	5.628	5.639	5.650
.53	5.660	5.671	5.682	5.693	5.703	5.714	5.725	5.735	5.746	5.757
.54	5.767	5.778	5.789	5.799	5.810	5.821	5.831	5.842	5.853	5.863
.55	5.874	5.885	5.895	5.906	5.917	5.927	5.938	5.949	5.960	5.970
.56	5.981	5.992	6.002	6.013	6.024	6.034	6.045	6.056	6.066	6.077
.57	6.088	6.098	6.109	6.120	6.130	6.141	6.152	6.162	6.173	6.184
.58	6.194	6.205	6.216	6.227	6.237	6.248	6.259	6.269	6.280	6.291
.59	6.301	6.312	6.323	6.333	6.344	6.355	6.365	6.376	6.387	6.397
.60	6.408	6.419	6.429	6.440	6.451	6.461	6.472	6.483	6.494	6.504
.61	6.515	6.526	6.536	6.547	6.558	6.568	6.579	6.590	6.600	6.611
.62	6.622	6.632	6.643	6.654	6.664	6.675	6.686	6.696	6.707	6.718
.63	6.728	6.739	6.750	6.761	6.771	6.782	6.793	6.803	6.814	6.825
.64	6.835	6.846	6.857	6.867	6.878	6.889	6.899	6.910	6.921	6.931
.65	6.942	6.953	6.963	6.974	6.985	6.996	7.006	7.017	7.028	7.038
.66	7.049	7.060	7.070	7.081	7.092	7.102	7.113	7.124	7.134	7.145
.67	7.156	7.166	7.177	7.188	7.198	7.209	7.220	7.230	7.241	7.252
.68	7.263	7.273	7.284	7.295	7.305	7.316	7.327	7.337	7.348	7.359
.69	7.369	7.380	7.391	7.401	7.412	7.423	7.433	7.444	7.455	7.465
.70	7.476	7.487	7.497	7.508	7.519	7.530	7.540	7.551	7.562	7.572
.71	7.583	7.594	7.604	7.615	7.626	7.636	7.647	7.658	7.668	7.679
.72	7.690	7.700	7.711	7.722	7.732	7.743	7.754	7.764	7.775	7.786
.73	7.797	7.807	7.818	7.829	7.839	7.850	7.861	7.871	7.882	7.893
.74	7.903	7.914	7.925	7.935	7.946	7.957	7.967	7.978	7.989	7.999
.75	8.010	8.021	8.031	8.042	8.053	8.064	8.074	8.085	8.096	8.106
.76	8.117	8.128	8.138	8.149	8.160	8.170	8.181	8.192	8.202	8.213
.77	8.224	8.234	8.245	8.256	8.266	8.277	8.288	8.298	8.309	8.320
.78	8.331	8.341	8.352	8.363	8.373	8.384	8.395	8.405	8.416	8.427
.79	8.437	8.448	8.459	8.469	8.480	8.491	8.501	8.512	8.523	8.533
.80	8.544	8.555	8.565	8.576	8.587	8.598	8.608	8.619	8.630	8.640
.81	8.651	8.662	8.672	8.683	8.694	8.704	8.715	8.726	8.736	8.747
.82	8.758	8.768	8.779	8.790	8.800	8.811	8.822	8.832	8.843	8.854
.83	8.865	8.875	8.886	8.897	8.907	8.918	8.929	8.939	8.950	8.961
.84	8.971	8.982	8.993	9.003	9.014	9.025	9.035	9.046	9.057	9.067
.85	9.078	9.089	9.099	9.110	9.121	9.132	9.142	9.153	9.164	9.174
.86	9.185	9.196	9.206	9.217	9.228	9.238	9.249	9.260	9.270	9.281
.87	9.292	9.302	9.313	9.324	9.334	9.345	9.356	9.366	9.377	9.388
.88	9.399	9.409	9.420	9.431	9.441	9.452	9.463	9.473	9.484	9.495
.89	9.505	9.516	9.527	9.537	9.548	9.559	9.569	9.580	9.591	9.601
.90	9.612	9.623	9.634	9.644	9.655	9.666	9.676	9.687	9.698	9.708
.91	9.719	9.730	9.740	9.751	9.762	9.772	9.783	9.794	9.804	9.815
.92	9.826	9.836	9.847	9.858	9.868	9.879	9.890	9.901	9.911	9.922
.93	9.933	9.943	9.954	9.965	9.975	9.986	9.997	10.007	10.018	10.029
.94	10.039	10.050	10.061	10.071	10.082	10.093	10.103	10.114	10.125	10.135
.95	10.146	10.157	10.168	10.178	10.189	10.200	10.210	10.221	10.232	10.242
.96	10.253	10.264	10.274	10.285	10.296	10.306	10.317	10.328	10.338	10.349
.97	10.360	10.370	10.381	10.392	10.402	10.413	10.424	10.435	10.445	10.456
.98	10.467	10.477	10.488	10.499	10.509	10.520	10.531	10.541	10.552	10.563
.99	10.573	10.584	10.595	10.605	10.616	10.627	10.637	10.648	10.659	10.669
1.00	10.6802									

WEIGHT IN POUNDS PER LINEAL FOOT FOR PIPE AND TUBING

Table II was calculated for steel pipe or tubes on the basis of one cubic inch of steel = .2833 pound. To convert these weights to weights for other materials, see weight factors, page 423. This table was calculated on an eight-slot Burkhardt machine by means of the formula:

$$W = 10.680158\,(D - t)\,t,$$

where W = weight of steel tube in pounds per foot;
D = outside diameter of tube in inches;
t = thickness in inches.

Table I may be used to interpolate for the weights of tubes varying by even 32nds or 64ths of an inch where the wall remains the same as in Table II. Table I was calculated by the formula:

$$D = 10.680158\,ta,$$

where D = difference in weight per foot;
t = thickness of wall in inches;
a = difference in outside diameters in inches.

Use of Table I. *Example.* Find weight per foot of tube $1\frac{41}{64}$ inch outside diameter $\times$ $\frac{3}{32}$ inch wall. The next size, given in Table II, smaller than $1\frac{41}{64}$ inch is $1\frac{5}{8}$ inch. Difference between $1\frac{41}{64}$ inch and $1\frac{5}{8}$ inch is $\frac{1}{64}$ inch.

Weight per foot, from Table II, of tube $1\frac{5}{8}$ inch outside diameter $\times$ $\frac{3}{32}$ inch wall .... = 1.533 pounds
Difference in weight per foot, from Table I, for $\frac{3}{32}$ inch wall and for difference, in outside diameter, of $\frac{1}{64}$ inch .... = .016

Weight per foot of tube $1\frac{41}{64}$ inch outside diameter $\times$ $\frac{3}{32}$ inch wall .... = 1.549 pounds

Table I.—Difference in Weight per Foot for Difference in Outside Diameter of "a", the Wall Remaining the Same for Steel Pipe and Tubing

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Difference in outside diameter, "a"						
B.W.G.	Inches	1/64	1/32	3/64	1/16	5/64	3/32	7/64
24	....	.0037	.0073	.0110				
23	....	.0042	.0083	.0125				
22	....	.0047	.0093	.0140				
21	....	.0053	.0107	.0160				
20	....	.0058	.0117	.0175	.0234	.0292	.0350	.0409
19	....	.0070	.0140	.0210	.0280	.0350	.0421	.0491
18	....	.0082	.0164	.0245	.0327	.0409	.0491	.0572
17	....	.0097	.0194	.0290	.0387	.0484	.0581	.0678
	1/16	.0104	.0209	.0313	.0417	.0521	.0626	.0730
16	....	.0108	.0217	.0325	.0434	.0542	.0651	.0759
15	....	.0120	.0240	.0360	.0481	.0601	.0721	.0841
14	....	.0139	.0277	.0416	.0554	.0693	.0831	.0970
	5/32	.0156	.0313	.0469	.0626	.0782	.0939	.1095
13	....	.0159	.0317	.0476	.0634	.0793	.0951	.1110
12	....	.0182	.0364	.0546	.0728	.0909	.1091	.1273
11	....	.0200	.0401	.0601	.0801	.1001	.1202	.1402
	1/8	.0209	.0417	.0626	.0834	.1043	.1252	.1460
10	....	.0224	.0447	.0671	.0894	.1118	.1342	.1565
9	....	.0247	.0494	.0741	.0988	.1235	.1482	.1729
	5/32	.0261	.0521	.0782	.1043	.1304	.1464	.1825
8	....	.0275	.0551	.0826	.1101	.1377	.1652	.1927
7	....	.0300	.0601	.0901	.1202	.1502	.1802	.2103
	3/16	.0313	.0626	.0939	.1252	.1564	.1877	.2190
6	....	.0339	.0678	.1016	.1355	.1694	.2033	.2371
	7/32	.0365	.0730	.1095	.1460	.1825	.2190	.2555
5	....	.0367	.0734	.1101	.1469	.1836	.2203	.2570
4	....	.0397	.0794	.1192	.1589	.1986	.2383	.2780
	1/4	.0417	.0834	.1252	.1669	.2086	.2503	.2920
3	....	.0432	.0864	.1297	.1729	.2161	.2593	.3025
	9/32	.0469	.0939	.1408	.1877	.2347	.2816	.3285
2	....	.0474	.0948	.1422	.1896	.2370	.2844	.3318
1	....	.0501	.1001	.1502	.2003	.2503	.3004	.3504
	5/16	.0521	.1043	.1564	.2086	.2607	.3129	.3650
	11/32	.0574	.1147	.1721	.2295	.2868	.3442	.4015
	3/8	.0626	.1252	.1877	.2503	.3129	.3755	.4381
	7/16	.0730	.1460	.2190	.2920	.3650	.4381	.5111
	1/2	.0834	.1669	.2503	.3338	.4172	.5006	.5841
	9/16	.0939	.1877	.2816	.3755	.4693	.5632	.6571
	5/8	.1043	.2086	.3129	.4172	.5215	.6258	.7301
	11/16	.1147	.2295	.3442	.4589	.5736	.6884	.8031
	3/4	.1252	.2503	.3755	.5006	.6258	.7509	.8761
	13/16	.1356	.2712	.4068	.5424	.6779	.8135	.9491
	7/8	.1460	.2920	.4381	.5841	.7301	.8761	1.022
	15/16	.1564	.3129	.4693	.6258	.7822	.9387	1.095
	1	.1669	.3338	.5006	.6675	.8344	1.001	1.168
	1 1/16	.1773	.3546	.5319	.7092	.8865	1.064	1.241
	1 1/8	.1877	.3755	.5632	.7509	.9387	1.126	1.314
	1 3/16	.1982	.3963	.5945	.7927	.9908	1.189	1.387
	1 1/4	.2086	.4172	.6258	.8344	1.043	1.252	1.460
	1 5/16	.2190	.4381	.6571	.8761	1.095	1.314	1.533
	1 3/8	.2295	.4589	.6884	.9178	1.147	1.377	1.606
	1 7/16	.2399	.4798	.7197	.9595	1.199	1.439	1.679
	1 1/2	.2503	.5006	.7509	1.001	1.252	1.502	1.752

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2
24	....	.0095	.0242	.0389	.0536	.0683	.0829	.0976	.1123
23	....	....	.0267	.0434	.0601	.0768	.0935	.1101	.1268
22	....	....	.0290	.0477	.0664	.0851	.1038	.1225	.1411
21	....	....	.0318	.0531	.0745	.0959	.1172	.1386	.1599
20	....	....	.0336	.0570	.0804	.1037	.1271	.1505	.1738
19	....	....	.0372	.0653	.0933	.1213	.1494	.1774	.2054
18	....	....	....	.0725	.1052	.1379	.1706	.2033	.2360
17	....	....	....	.0802	.1189	.1577	.1964	.2351	.2738
	1/16	....	....	.0834	.1252	.1669	.2086	.2503	.2920
16	....	....	....	....	.1284	.1718	.2152	.2586	.3020
15	....	....	....	....	.1369	.1849	.2330	.2811	.3291
14	....	....	....	....	.1480	.2034	.2588	.3142	.3697
	3/32	....	....	....	....	.2190	.2816	.3442	.4068
13	....	....	....	....	....	.2207	.2841	.3475	.4109
12	....	....	....	....	....	....	.3097	.3824	.4552
11	....	....	....	....	....	....	.3268	.4069	.4870
	1/8	....	....	....	....	....	.3338	.4172	.5006
10	....	....	....	....	....	....	....	.4344	.5238
9	....	....	....	....	....	....	....	.4576	.5564
	5/32	....	....	....	....	....	....	....	.5736
8	....	....	....	....	....	....	....	....	.5903

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
24	....	.1270	.1417	.1564	.1711	.1857	.2004	.2151	.2298
23	....	.1435	.1602	.1769	.1936	.2103	.2270	.2436	.2603
22	....	.1598	.1785	.1972	.2159	.2346	.2533	.2720	.2907
21	....	.1813	.2027	.2240	.2454	.2667	.2881	.3095	.3308
20	....	.1972	.2205	.2439	.2673	.2906	.3140	.3374	.3607
19	....	.2335	.2615	.2895	.3176	.3456	.3737	.4017	.4297
18	....	.2687	.3014	.3341	.3669	.3996	.4323	.4650	.4977
17	....	.3125	.3512	.3899	.4287	.4674	.5061	.5448	.5835
	1/16	.3338	.3755	.4172	.4589	.5006	.5424	.5841	.6258
16	....	.3454	.3888	.4321	.4755	.5189	.5623	.6057	.6491
15	....	.3772	.4252	.4733	.5214	.5694	.6175	.6655	.7136
14	....	.4251	.4805	.5359	.5913	.6467	.7021	.7575	.8129
	3/32	.4693	.5319	.5945	.6571	.7197	.7822	.8448	.9074
13	....	.4743	.5377	.6012	.6646	.7280	.7914	.8548	.9182
12	....	.5279	.6007	.6735	.7462	.8190	.8917	.9645	1.037
11	....	.5671	.6472	.7273	.8074	.8875	.9676	1.048	1.128
	1/8	.5841	.6675	.7509	.8344	.9178	1.001	1.085	1.168
10	....	.6132	.7027	.7921	.8816	.9710	1.060	1.150	1.239
9	....	.6552	.7540	.8528	.9516	1.050	1.149	1.248	1.347
	5/32	.6779	.7822	.8865	.9908	1.095	1.199	1.304	1.408
8	....	.7005	.8106	.9208	1.031	1.141	1.251	1.361	1.471
7	....	.7353	.8555	.9756	1.096	1.216	1.336	1.456	1.576
	3/16	.7509	.8761	1.001	1.126	1.252	1.377	1.502	1.627
6	....	....	.9149	1.050	1.186	1.321	1.457	1.592	1.728
	7/32	....	....	1.095	1.241	1.387	1.533	1.679	1.825
5	....	....	....	1.098	1.245	1.392	1.539	1.686	1.833
4	....	....	....	....	1.301	1.460	1.619	1.778	1.937
	1/4	....	....	....	1.335	1.502	1.669	1.836	2.003
3	....	....	....	....	....	1.531	1.704	1.877	2.050
	9/32	....	....	....	....	....	1.784	1.971	2.159
2	....	....	....	....	....	....	1.793	1.982	2.172
1	....	....	....	....	....	....	....	2.043	2.243
	5/16	....	....	....	....	....	....	2.086	2.295

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	1 1/16	1 1/8	1 3/16	1 1/4	1 5/16	1 3/8	1 7/16	1 1/2
20	....	.3841	.4074	.4308	.4542	.4775	.5009	.5243	.5476
19	....	.4578	.4858	.5138	.5419	.5699	.5979	.6260	.6540
18	....	.5304	.5631	.5958	.6285	.6612	.6939	.7266	.7594
17	....	.6222	.6610	.6997	.7384	.7771	.8158	.8545	.8932
	1/16	.6675	.7092	.7509	.7927	.8344	.8761	.9178	.9595
16	....	.6925	.7359	.7793	.8226	.8660	.9094	.9528	.9962
15	....	.7617	.8097	.8578	.9058	.9539	1.002	1.050	1.098
14	....	.8683	.9237	.9791	1.034	1.090	1.145	1.201	1.256
	3/32	.9700	1.033	1.095	1.158	1.220	1.283	1.345	1.408
13	....	.9816	1.045	1.108	1.172	1.235	1.299	1.362	1.426
12	....	1.110	1.183	1.256	1.328	1.401	1.474	1.547	1.619
11	....	1.208	1.288	1.368	1.448	1.528	1.608	1.689	1.769
	1/8	1.252	1.335	1.418	1.502	1.585	1.669	1.752	1.836
10	....	1.329	1.418	1.508	1.597	1.687	1.776	1.865	1.955
9	....	1.446	1.544	1.643	1.742	1.841	1.939	2.038	2.137
	5/32	1.512	1.617	1.721	1.825	1.930	2.034	2.138	2.242
8	....	1.582	1.692	1.802	1.912	2.022	2.132	2.242	2.353
7	....	1.697	1.817	1.937	2.057	2.177	2.297	2.417	2.538
	3/16	1.752	1.877	2.003	2.128	2.253	2.378	2.503	2.628
6	....	1.863	1.999	2.134	2.270	2.405	2.541	2.676	2.812
	7/32	1.971	2.117	2.263	2.409	2.555	2.701	2.847	2.993
5	....	1.980	2.126	2.273	2.420	2.567	2.714	2.861	3.008
4	....	2.096	2.255	2.414	2.572	2.731	2.890	3.049	3.208
	1/4	2.169	2.336	2.503	2.670	2.837	3.004	3.171	3.338
3	....	2.223	2.395	2.568	2.741	2.914	3.087	3.260	3.433
	9/32	2.347	2.534	2.722	2.910	3.098	3.285	3.473	3.661
2	....	2.361	2.551	2.740	2.930	3.120	3.309	3.499	3.688
1	....	2.443	2.643	2.844	3.044	3.244	3.444	3.645	3.845
	5/16	2.503	2.712	2.920	3.129	3.338	3.546	3.755	3.963
	11/32	2.639	2.868	3.098	3.327	3.557	3.786	4.015	4.245
	3/8	....	3.004	3.254	3.504	3.755	4.005	4.255	4.506
	7/16	....	....	....	....	4.088	4.381	4.673	4.965
	1/2	....	....	....	....	....	....	....	5.340

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	1 9/16	1 5/8	1 11/16	1 3/4	1 13/16	1 7/8	1 15/16	2
20	....	.5710	.5944	.6177	.6411	.6644	.6878	.7112	.7345
19	....	.6820	.7101	.7381	.7662	.7942	.8222	.8503	.8783
18	....	.7921	.8248	.8575	.8902	.9229	.9556	.9883	1.021
17	....	.9320	.9707	1.009	1.048	1.087	1.126	1.164	1.203
	1/16	1.001	1.043	1.085	1.126	1.168	1.210	1.252	1.293
16	....	1.040	1.083	1.126	1.170	1.213	1.257	1.300	1.343
15	....	1.146	1.194	1.242	1.290	1.338	1.386	1.435	1.483
14	....	1.312	1.367	1.422	1.478	1.533	1.589	1.644	1.699
	3/32	1.471	1.533	1.596	1.658	1.721	1.784	1.846	1.909
13	....	1.489	1.552	1.616	1.679	1.743	1.806	1.869	1.933
12	....	1.692	1.765	1.838	1.910	1.983	2.056	2.129	2.201
11	....	1.849	1.929	2.009	2.089	2.169	2.249	2.329	2.409
	1/8	1.919	2.003	2.086	2.169	2.253	2.336	2.420	2.503
10	....	2.044	2.134	2.223	2.313	2.402	2.492	2.581	2.671
9	....	2.236	2.335	2.433	2.532	2.631	2.730	2.829	2.927
	5/32	2.347	2.451	2.555	2.660	2.764	2.868	2.973	3.077
8	....	2.463	2.573	2.683	2.793	2.903	3.013	3.124	3.234
7	....	2.658	2.778	2.898	3.018	3.138	3.259	3.379	3.499
	3/16	2.753	2.879	3.004	3.129	3.254	3.379	3.504	3.630
6	....	2.947	3.083	3.219	3.354	3.490	3.625	3.761	3.896
	7/32	3.139	3.285	3.431	3.577	3.723	3.869	4.015	4.162
5	....	3.154	3.301	3.448	3.595	3.742	3.889	4.035	4.182
4	....	3.367	3.526	3.684	3.843	4.002	4.161	4.320	4.479
	1/4	3.504	3.671	3.838	4.005	4.172	4.339	4.506	4.673
3	....	3.606	3.779	3.951	4.124	4.297	4.470	4.643	4.816
	9/32	3.849	4.036	4.224	4.412	4.600	4.787	4.975	5.163
2	....	3.878	4.067	4.257	4.447	4.636	4.826	5.015	5.205
1	....	4.045	4.245	4.446	4.646	4.846	5.046	5.247	5.447
	5/16	4.172	4.381	4.589	4.798	5.006	5.215	5.424	5.632
	11/32	4.474	4.704	4.933	5.163	5.392	5.622	5.851	6.081
	3/8	4.756	5.006	5.257	5.507	5.757	6.008	6.258	6.508
	7/16	5.257	5.549	5.841	6.133	6.425	6.717	7.009	7.301
	1/2	5.674	6.008	6.341	6.675	7.009	7.343	7.676	8.010
	9/16	....	....	6.759	7.134	7.509	7.885	8.260	8.636
	5/8	....	....	....	....	....	8.344	8.761	9.178
	11/16	....	....	....	....	....	....	....	9.637

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	2⅛	2¼	2⅜	2½	2⅝	2¾	2⅞	3
20	....	.7813	.8280	.8747	.9214	.9682	1.015	1.062	1.108
19	....	.9344	.9904	1.047	1.103	1.159	1.215	1.271	1.327
18	....	1.086	1.152	1.217	1.283	1.348	1.414	1.479	1.544
17	....	1.280	1.358	1.435	1.513	1.590	1.668	1.745	1.822
	1/16	1.377	1.460	1.544	1.627	1.710	1.794	1.877	1.961
16	....	1.430	1.517	1.604	1.690	1.777	1.864	1.951	2.038
15	....	1.579	1.675	1.771	1.867	1.963	2.059	2.155	2.252
14	....	1.810	1.921	2.032	2.143	2.253	2.364	2.475	2.586
	3/32	2.034	2.159	2.284	2.409	2.534	2.660	2.785	2.910
13	....	2.060	2.186	2.313	2.440	2.567	2.694	2.821	2.947
12	....	2.347	2.492	2.638	2.783	2.929	3.074	3.220	3.366
11	....	2.570	2.730	2.890	3.050	3.210	3.371	3.531	3.691
	1/8	2.670	2.837	3.004	3.171	3.338	3.504	3.671	3.838
10	....	2.849	3.028	3.207	3.386	3.565	3.744	3.923	4.102
9	....	3.125	3.323	3.520	3.718	3.915	4.113	4.310	4.508
	5/32	3.285	3.494	3.703	3.911	4.120	4.328	4.537	4.746
8	....	3.454	3.674	3.895	4.115	4.335	4.555	4.776	4.996
7	....	3.739	3.979	4.220	4.460	4.700	4.941	5.181	5.421
	3/16	3.880	4.130	4.381	4.631	4.881	5.131	5.382	5.632
6	....	4.167	4.438	4.709	4.980	5.251	5.522	5.793	6.064
	7/32	4.454	4.746	5.038	5.330	5.622	5.914	6.206	6.498
5	....	4.476	4.770	5.063	5.357	5.651	5.945	6.238	6.532
4	....	4.797	5.114	5.432	5.750	6.067	6.385	6.703	7.021
	1/4	5.006	5.340	5.674	6.008	6.341	6.675	7.009	7.343
3	....	5.162	5.507	5.853	6.199	6.545	6.891	7.236	7.582
	9/32	5.538	5.914	6.289	6.665	7.040	7.416	7.791	8.167
2	....	5.584	5.963	6.342	6.721	7.101	7.480	7.859	8.238
1	....	5.847	6.248	6.648	7.049	7.449	7.850	8.250	8.651
	5/16	6.049	6.467	6.884	7.301	7.718	8.135	8.552	8.970
	11/32	6.540	6.998	7.457	7.916	8.375	8.834	9.293	9.752
	3/8	7.009	7.509	8.010	8.511	9.011	9.512	10.01	10.51
	7/16	7.885	8.469	9.053	9.637	10.22	10.81	11.39	11.97
	1/2	8.678	9.345	10.01	10.68	11.35	12.02	12.68	13.35
	9/16	9.387	10.14	10.89	11.64	12.39	13.14	13.89	14.64
	5/8	10.01	10.85	11.68	12.52	13.35	14.18	15.02	15.85
	11/16	10.55	11.47	12.39	13.31	14.23	15.14	16.06	16.98
	3/4	....	12.02	13.02	14.02	15.02	16.02	17.02	18.02
	13/16	....	....	13.56	14.64	15.73	16.81	17.90	18.98
	7/8	....	....	....	....	16.35	17.52	18.69	19.86
	15/16	....	....	....	....	....	18.15	19.40	20.65
	1	....	....	....	....	....	......	......	21.36

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	3⅛	3¼	3⅜	3½	3⅝	3¾	3⅞	4
18	....	1.610	1.675	1.741	1.806	1.871	1.937	2.002	2.068
17	....	1.900	1.977	2.055	2.132	2.210	2.287	2.364	2.442
	1/16	2.044	2.128	2.211	2.295	2.378	2.461	2.545	2.628
16	....	2.124	2.211	2.298	2.385	2.471	2.558	2.645	2.732
15	....	2.348	2.444	2.540	2.636	2.732	2.828	2.924	3.021
14	....	2.697	2.807	2.918	3.029	3.140	3.251	3.361	3.472
	3/32	3.035	3.160	3.285	3.411	3.536	3.661	3.786	3.911
13	....	3.074	3.201	3.328	3.455	3.582	3.708	3.835	3.962
12	....	3.511	3.657	3.802	3.948	4.093	4.239	4.384	4.530
11	....	3.851	4.011	4.172	4.332	4.492	4.652	4.812	4.973
	1/8	4.005	4.172	4.339	4.506	4.673	4.839	5.006	5.173
10	....	4.281	4.459	4.638	4.817	4.996	5.175	5.354	5.533
9	....	4.706	4.903	5.101	5.298	5.496	5.694	5.891	6.089
	5/32	4.954	5.163	5.371	5.580	5.789	5.997	6.206	6.414
8	....	5.216	5.436	5.657	5.877	6.097	6.318	6.538	6.758
7	....	5.662	5.902	6.142	6.382	6.623	6.863	7.103	7.344
	3/16	5.882	6.133	6.383	6.633	6.884	7.134	7.384	7.635
6	....	6.335	6.606	6.877	7.148	7.419	7.690	7.961	8.232
	7/32	6.790	7.082	7.374	7.666	7.958	8.250	8.542	8.834
5	....	6.826	7.119	7.413	7.707	8.001	8.294	8.588	8.882
4	....	7.338	7.656	7.974	8.292	8.609	8.927	9.245	9.563
	1/4	7.676	8.010	8.344	8.678	9.011	9.345	9.679	10.01
3	....	7.928	8.274	8.619	8.965	9.311	9.657	10.00	10.35
	9/32	8.542	8.918	9.293	9.668	10.04	10.42	10.79	11.17
2	....	8.617	8.996	9.376	9.755	10.13	10.51	10.89	11.27
1	....	9.051	9.452	9.852	10.25	10.65	11.05	11.45	11.85
	5/16	9.387	9.804	10.22	10.64	11.06	11.47	11.89	12.31
	11/32	10.21	10.67	11.13	11.59	12.05	12.51	12.96	13.42
	3/8	11.01	11.51	12.02	12.52	13.02	13.52	14.02	14.52
	7/16	12.56	13.14	13.73	14.31	14.89	15.48	16.06	16.65
	1/2	14.02	14.69	15.35	16.02	16.69	17.36	18.02	18.69
	9/16	15.39	16.15	16.90	17.65	18.40	19.15	19.90	20.65
	5/8	16.69	17.52	18.36	19.19	20.03	20.86	21.69	22.53
	11/16	17.90	18.82	19.73	20.65	21.57	22.49	23.40	24.32
	3/4	19.02	20.03	21.03	22.03	23.03	24.03	25.03	26.03
	13/16	20.07	21.15	22.24	23.32	24.41	25.49	26.58	27.66
	7/8	21.03	22.19	23.36	24.53	25.70	26.87	28.04	29.20
	15/16	21.90	23.15	24.41	25.66	26.91	28.16	29.41	30.66
	1	22.70	24.03	25.37	26.70	28.04	29.37	30.71	32.04
	1 1/16	23.40	24.82	26.24	27.66	29.08	30.50	31.92	33.33
	1 1/8	....	....	27.03	28.54	30.04	31.54	33.04	34.54
	1 3/16	....	....	....	29.33	30.91	32.50	34.08	35.67
	1 1/4	....	....	....	....	....	33.38	35.04	36.71
	1 5/16	....	....	....	....	....	....	35.92	37.67

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	4⅛	4¼	4⅜	4½	4⅝	4¾	4⅞	5
18	....	2.133	2.199	2.264	2.329	2.395	2.460	2.526	2.591
17	....	2.519	2.597	2.674	2.752	2.829	2.906	2.984	3.061
	1/16	2.712	2.795	2.879	2.962	3.046	3.129	3.212	3.296
16	....	2.818	2.905	2.992	3.079	3.166	3.252	3.339	3.426
15	....	3.117	3.213	3.309	3.405	3.501	3.597	3.693	3.789
14	....	3.583	3.694	3.805	3.915	4.026	4.137	4.248	4.359
	3/32	4.036	4.162	4.287	4.412	4.537	4.662	4.787	4.912
13	....	4.089	4.216	4.343	4.469	4.596	4.723	4.850	4.977
12	....	4.675	4.821	4.966	5.112	5.257	5.403	5.548	5.694
11	....	5.133	5.293	5.453	5.613	5.774	5.934	6.094	6.254
	⅛	5.340	5.507	5.674	5.841	6.008	6.174	6.341	6.508
10	....	5.712	5.891	6.069	6.248	6.427	6.606	6.785	6.964
9	....	6.286	6.484	6.681	6.879	7.077	7.274	7.472	7.669
	5/32	6.623	6.832	7.040	7.249	7.457	7.666	7.875	8.083
8	....	6.978	7.199	7.419	7.639	7.860	8.080	8.300	8.520
7	....	7.584	7.824	8.065	8.305	8.545	8.785	9.026	9.266
	3/16	7.885	8.135	8.386	8.636	8.886	9.137	9.387	9.637
6	....	8.503	8.774	9.045	9.316	9.587	9.858	10.13	10.40
	7/32	9.126	9.418	9.710	10.00	10.29	10.59	10.88	11.17
5	....	9.175	9.469	9.763	10.06	10.35	10.64	10.94	11.23
4	....	9.880	10.20	10.52	10.83	11.15	11.47	11.79	12.10
	¼	10.35	10.68	11.01	11.35	11.68	12.02	12.35	12.68
3	....	10.69	11.04	11.39	11.73	12.08	12.42	12.77	13.11
	9/32	11.55	11.92	12.30	12.67	13.05	13.42	13.80	14.17
2	....	11.65	12.03	12.41	12.79	13.17	13.55	13.93	14.30
1	....	12.26	12.66	13.06	13.46	13.86	14.26	14.66	15.06
	5/16	12.72	13.14	13.56	13.98	14.39	14.81	15.23	15.64
	11/32	13.88	14.34	14.80	15.26	15.72	16.18	16.64	17.09
	⅜	15.02	15.52	16.02	16.52	17.02	17.52	18.02	18.52
	7/16	17.23	17.81	18.40	18.98	19.57	20.15	20.73	21.32
	½	19.36	20.03	20.69	21.36	22.03	22.70	23.36	24.03
	9/16	21.40	22.15	22.90	23.65	24.41	25.16	25.91	26.66
	⅝	23.36	24.20	25.03	25.87	26.70	27.53	28.37	29.20
	11/16	25.24	26.16	27.08	27.99	28.91	29.83	30.75	31.66
	¾	27.03	28.04	29.04	30.04	31.04	32.04	33.04	34.04
	13/16	28.74	29.83	30.91	32.00	33.08	34.17	35.25	36.34
	⅞	30.37	31.54	32.71	33.88	35.04	36.21	37.38	38.55
	15/16	31.92	33.17	34.42	35.67	36.92	38.17	39.42	40.68
	1	33.38	34.71	36.05	37.38	38.72	40.05	41.39	42.72
	1 1/16	34.75	36.17	37.59	39.01	40.43	41.84	43.26	44.68
	1⅛	36.05	37.55	39.05	40.55	42.05	43.56	45.06	46.56
	1 3/16	37.26	38.84	40.43	42.01	43.60	45.18	46.77	48.35
	1¼	38.38	40.05	41.72	43.39	45.06	46.73	48.39	50.06
	1 5/16	39.42	41.18	42.93	44.68	46.43	48.19	49.94	51.69
	1⅜	40.38	42.22	44.06	45.89	47.73	49.56	51.40	53.23
	1 7/16	....	43.18	45.10	47.02	48.94	50.86	52.77	54.69
	1½	....	....	....	48.06	50.06	52.07	54.07	56.07

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	5 1/8	5 1/4	5 3/8	5 1/2	5 5/8	5 3/4	5 7/8	6
12	....	5.839	5.985	6.130	6.276	6.421	6.567	6.712	6.858
11	....	6.415	6.575	6.735	6.895	7.055	7.216	7.376	7.536
	1/8	6.675	6.842	7.009	7.176	7.343	7.509	7.676	7.843
10	....	7.143	7.322	7.501	7.680	7.858	8.037	8.216	8.395
9	....	7.867	8.065	8.262	8.460	8.657	8.855	9.052	9.250
	5/32	8.292	8.500	8.709	8.918	9.126	9.335	9.543	9.752
8	....	8.741	8.961	9.181	9.401	9.622	9.842	10.06	10.28
7	....	9.506	9.747	9.987	10.23	10.47	10.71	10.95	11.19
	3/16	9.887	10.14	10.39	10.64	10.89	11.14	11.39	11.64
6	....	10.67	10.94	11.21	11.48	11.76	12.03	12.30	12.57
	7/32	11.46	11.75	12.05	12.34	12.63	12.92	13.21	13.51
5	....	11.52	11.82	12.11	12.41	12.70	12.99	13.29	13.58
4	....	12.42	12.74	13.06	13.38	13.69	14.01	14.33	14.65
	1/4	13.02	13.35	13.68	14.02	14.35	14.69	15.02	15.35
3	....	13.46	13.81	14.15	14.50	14.84	15.19	15.53	15.88
	9/32	14.55	14.93	15.30	15.68	16.05	16.43	16.80	17.18
2	....	14.68	15.06	15.44	15.82	16.20	16.58	16.96	17.34
1	....	15.46	15.86	16.26	16.66	17.06	17.46	17.86	18.26
	5/16	16.06	16.48	16.90	17.31	17.73	18.15	18.57	18.98
	11/32	17.55	18.01	18.47	18.93	19.39	19.85	20.31	20.77
	3/8	19.02	19.52	20.03	20.53	21.03	21.53	22.03	22.53
	7/16	21.90	22.49	23.07	23.65	24.24	24.82	25.41	25.99
	1/2	24.70	25.37	26.03	26.70	27.37	28.04	28.70	29.37
	9/16	27.41	28.16	28.91	29.66	30.41	31.16	31.92	32.67
	5/8	30.04	30.87	31.71	32.54	33.38	34.21	35.04	35.88
	11/16	32.58	33.50	34.42	35.34	36.25	37.17	38.09	39.01
	3/4	35.04	36.05	37.05	38.05	39.05	40.05	41.05	42.05
	13/16	37.42	38.51	39.59	40.68	41.76	42.85	43.93	45.02
	7/8	39.72	40.88	42.05	43.22	44.39	45.56	46.73	47.89
	15/16	41.93	43.18	44.43	45.68	46.93	48.19	49.44	50.69
	1	44.06	45.39	46.73	48.06	49.40	50.73	52.07	53.40
	1 1/16	46.10	47.52	48.94	50.36	51.77	53.19	54.61	56.03
	1 1/8	48.06	49.56	51.06	52.57	54.07	55.57	57.07	58.57
	1 3/16	49.94	51.52	53.11	54.69	56.28	57.86	59.45	61.04
	1 1/4	51.73	53.40	55.07	56.74	58.41	60.08	61.74	63.41
	1 5/16	53.44	55.19	56.95	58.70	60.45	62.20	63.96	65.71
	1 3/8	55.07	56.91	58.74	60.58	62.41	64.25	66.08	67.92
	1 7/16	56.61	58.53	60.45	62.37	64.29	66.21	68.13	70.05
	1 1/2	58.07	60.08	62.08	64.08	66.08	68.09	70.09	72.09

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	6⅛	6¼	6⅜	6½	6⅝	6¾	6⅞	7
12	....	7.003	7.149	7.294	7.440	7.586	7.731	7.877	8.022
11	....	7.696	7.856	8.017	8.177	8.337	8.497	8.657	8.818
	⅛	8.010	8.177	8.344	8.511	8.678	8.845	9.011	9.178
10	....	8.574	8.753	8.932	9.111	9.290	9.468	9.647	9.826
9	....	9.448	9.645	9.843	10.04	10.24	10.44	10.63	10.83
	5/32	9.960	10.17	10.38	10.59	10.79	11.00	11.21	11.42
8	....	10.50	10.72	10.94	11.16	11.38	11.60	11.82	12.04
7	....	11.43	11.67	11.91	12.15	12.39	12.63	12.87	13.11
	3/16	11.89	12.14	12.39	12.64	12.89	13.14	13.39	13.64
6	....	12.84	13.11	13.38	13.65	13.92	14.19	14.47	14.74
	7/32	13.80	14.09	14.38	14.67	14.97	15.26	15.55	15.84
5	....	13.87	14.17	14.46	14.76	15.05	15.34	15.64	15.93
4	....	14.96	15.28	15.60	15.92	16.23	16.55	16.87	17.19
	¼	15.69	16.02	16.35	16.69	17.02	17.36	17.69	18.02
3	....	16.23	16.57	16.92	17.26	17.61	17.96	18.30	18.65
	9/32	17.55	17.93	18.30	18.68	19.06	19.43	19.81	20.18
2	....	17.72	18.10	18.48	18.85	19.23	19.61	19.99	20.37
1	....	18.66	19.06	19.46	19.87	20.27	20.67	21.07	21.47
	5/16	19.40	19.82	20.23	20.65	21.07	21.49	21.90	22.32
	11/32	21.22	21.68	22.14	22.60	23.06	23.52	23.98	24.44
	⅜	23.03	23.53	24.03	24.53	25.03	25.53	26.03	26.53
	7/16	26.58	27.16	27.74	28.33	28.91	29.50	30.08	30.66
	½	30.04	30.71	31.37	32.04	32.71	33.38	34.04	34.71
	9/16	33.42	34.17	34.92	35.67	36.42	37.17	37.92	38.67
	⅝	36.71	37.55	38.38	39.22	40.05	40.88	41.72	42.55
	11/16	39.93	40.84	41.76	42.68	43.60	44.51	45.43	46.35
	¾	43.05	44.06	45.06	46.06	47.06	48.06	49.06	50.06
	13/16	46.10	47.18	48.27	49.35	50.44	51.52	52.61	53.69
	⅞	49.06	50.23	51.40	52.57	53.73	54.90	56.07	57.24
	15/16	51.94	53.19	54.44	55.70	56.95	58.20	59.45	60.70
	1	54.74	56.07	57.41	58.74	60.08	61.41	62.75	64.08
	1 1/16	57.45	58.87	60.28	61.70	63.12	64.54	65.96	67.38
	1⅛	60.08	61.58	63.08	64.58	66.08	67.59	69.09	70.59
	1 3/16	62.62	64.21	65.79	67.38	68.96	70.55	72.13	73.72
	1¼	65.08	66.75	68.42	70.09	71.76	73.43	75.09	76.76
	1 5/16	67.46	69.21	70.96	72.72	74.47	76.22	77.97	79.73
	1⅜	69.75	71.59	73.43	75.26	77.10	78.93	80.77	82.60
	1 7/16	71.97	73.89	75.80	77.72	79.64	81.56	83.48	85.40
	1½	74.09	76.10	78.10	80.10	82.10	84.11	86.11	88.11

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	7⅛	7¼	7⅜	7½	7⅝	7¾	7⅞	8
10	....	10.01	10.18	10.36	10.54	10.72	10.90	11.08	11.26
9	....	11.03	11.23	11.42	11.62	11.82	12.02	12.21	12.41
	5/32	11.63	11.84	12.05	12.26	12.46	12.67	12.88	13.09
8	....	12.27	12.49	12.71	12.93	13.15	13.37	13.59	13.81
7	....	13.35	13.59	13.83	14.07	14.31	14.55	14.79	15.03
	3/16	13.89	14.14	14.39	14.64	14.89	15.14	15.39	15.64
6	....	15.01	15.28	15.55	15.82	16.09	16.36	16.63	16.90
	7/32	16.13	16.43	16.72	17.01	17.30	17.60	17.89	18.18
5	....	16.22	16.52	16.81	17.11	17.40	17.69	17.99	18.28
4	....	17.51	17.82	18.14	18.46	18.78	19.09	19.41	19.73
	¼	18.36	18.69	19.02	19.36	19.69	20.03	20.36	20.69
3	....	18.99	19.34	19.68	20.03	20.38	20.72	21.07	21.41
	9/32	20.56	20.93	21.31	21.68	22.06	22.43	22.81	23.19
2	....	20.75	21.13	21.51	21.89	22.27	22.65	23.02	23.40
1	....	21.87	22.27	22.67	23.07	23.47	23.87	24.27	24.67
	5/16	22.74	23.15	23.57	23.99	24.41	24.82	25.24	25.66
	11/32	24.90	25.35	25.81	26.27	26.73	27.19	27.65	28.11
	⅜	27.03	27.53	28.04	28.54	29.04	29.54	30.04	30.54
	7/16	31.25	31.83	32.42	33.00	33.58	34.17	34.75	35.34
	½	35.38	36.05	36.71	37.38	38.05	38.72	39.38	40.05
	9/16	39.42	40.18	40.93	41.68	42.43	43.18	43.93	44.68
	⅝	43.39	44.22	45.06	45.89	46.73	47.56	48.39	49.23
	11/16	47.27	48.19	49.10	50.02	50.94	51.86	52.77	53.69
	¾	51.06	52.07	53.07	54.07	55.07	56.07	57.07	58.07
	13/16	54.78	55.86	56.95	58.03	59.12	60.20	61.29	62.37
	⅞	58.41	59.58	60.74	61.91	63.08	64.25	65.42	66.58
	15/16	61.95	63.20	64.46	65.71	66.96	68.21	69.46	70.71
	1	65.42	66.75	68.09	69.42	70.76	72.09	73.43	74.76
	1 1/16	68.80	70.21	71.63	73.05	74.47	75.89	77.31	78.72
	1⅛	72.09	73.59	75.09	76.60	78.10	79.60	81.10	82.60
	1 3/16	75.30	76.89	78.47	80.06	81.64	83.23	84.82	86.40
	1¼	78.43	80.10	81.77	83.44	85.11	86.78	88.45	90.11
	1 5/16	81.48	83.23	84.98	86.73	88.49	90.24	91.99	93.74
	1⅜	84.44	86.28	88.11	89.95	91.78	93.62	95.45	97.29
	1 7/16	87.32	89.24	91.16	93.08	95.00	96.91	98.83	100.8
	1½	90.11	92.12	94.12	96.12	98.12	100.1	102.1	104.1

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	8⅛	8¼	8⅜	8½	8⅝	8¾	8⅞	9
10	....	11.44	11.62	11.79	11.97	12.15	12.33	12.51	12.69
9	....	12.61	12.81	13.00	13.20	13.40	13.60	13.79	13.99
	5/32	13.30	13.51	13.72	13.92	14.13	14.34	14.55	14.76
8	....	14.03	14.25	14.47	14.69	14.91	15.13	15.35	15.57
7	....	15.27	15.51	15.75	15.99	16.23	16.48	16.72	16.96
	3/16	15.90	16.15	16.40	16.65	16.90	17.15	17.40	17.65
6	....	17.18	17.45	17.72	17.99	18.26	18.53	18.80	19.07
	7/32	18.47	18.76	19.06	19.35	19.64	19.93	20.22	20.52
5	....	18.57	18.87	19.16	19.45	19.75	20.04	20.34	20.63
4	....	20.05	20.37	20.68	21.00	21.32	21.64	21.95	22.27
	¼	21.03	21.36	21.69	22.03	22.36	22.70	23.03	23.36
3	....	21.76	22.10	22.45	22.80	23.14	23.49	23.83	24.18
	9/32	23.56	23.94	24.31	24.69	25.06	25.44	25.81	26.19
2	....	23.78	24.16	24.54	24.92	25.30	25.68	26.06	26.44
1	....	25.07	25.47	25.87	26.27	26.67	27.07	27.47	27.88
	5/16	26.07	26.49	26.91	27.33	27.74	28.16	28.58	29.00
	11/32	28.57	29.03	29.49	29.94	30.40	30.86	31.32	31.78
	⅜	31.04	31.54	32.04	32.54	33.04	33.54	34.04	34.54
	7/16	35.92	36.50	37.09	37.67	38.26	38.84	39.42	40.01
	½	40.72	41.39	42.05	42.72	43.39	44.06	44.72	45.39
	9/16	45.43	46.18	46.93	47.69	48.44	49.19	49.94	50.69
	⅝	50.06	50.90	51.73	52.57	53.40	54.24	55.07	55.90
	11/16	54.61	55.53	56.45	57.36	58.28	59.20	60.12	61.04
	¾	59.07	60.08	61.08	62.08	63.08	64.08	65.08	66.08
	13/16	63.46	64.54	65.62	66.71	67.79	68.88	69.96	71.05
	⅞	67.75	68.92	70.09	71.26	72.42	73.59	74.76	75.93
	15/16	71.97	73.22	74.47	75.72	76.97	78.22	79.48	80.73
	1	76.10	77.43	78.77	80.10	81.44	82.77	84.11	85.44
	1 1/16	80.14	81.56	82.98	84.40	85.82	87.24	88.65	90.07
	1⅛	84.11	85.61	87.11	88.61	90.11	91.62	93.12	94.62
	1 3/16	87.99	89.57	91.16	92.74	94.33	95.91	97.50	99.08
	1¼	91.78	93.45	95.12	96.79	98.46	100.1	101.8	103.5
	1 5/16	95.50	97.25	99.00	100.8	102.5	104.3	106.0	107.8
	1⅜	99.13	101.0	102.8	104.6	106.5	108.3	110.1	112.0
	1 7/16	102.7	104.6	106.5	108.4	110.3	112.3	114.2	116.1
	1½	106.1	108.1	110.1	112.1	114.1	116.1	118.1	120.2

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	9⅛	9¼	9⅜	9½	9⅝	9¾	9⅞	10
10	....	12.87	13.05	13.23	13.40	13.58	13.76	13.94	14.12
9	....	14.19	14.39	14.58	14.78	14.98	15.18	15.38	15.57
	5/32	14.97	15.18	15.38	15.59	15.80	16.01	16.22	16.43
8	....	15.79	16.01	16.23	16.45	16.67	16.89	17.11	17.33
7	....	17.20	17.44	17.68	17.92	18.16	18.40	18.64	18.88
	3/16	17.90	18.15	18.40	18.65	18.90	19.15	19.40	19.65
6	....	19.34	19.61	19.89	20.16	20.43	20.70	20.97	21.24
	7/32	20.81	21.10	21.39	21.68	21.98	22.27	22.56	22.85
5	....	20.92	21.22	21.51	21.80	22.10	22.39	22.69	22.98
4	....	22.59	22.91	23.23	23.54	23.86	24.18	24.50	24.81
	¼	23.70	24.03	24.36	24.70	25.03	25.37	25.70	26.03
3	....	24.52	24.87	25.22	25.56	25.91	26.25	26.60	26.95
	9/32	26.56	26.94	27.32	27.69	28.07	28.44	28.82	29.19
2	....	26.82	27.20	27.57	27.95	28.33	28.71	29.09	29.47
1	....	28.28	28.68	29.08	29.48	29.88	30.28	30.68	31.08
	5/16	29.41	29.83	30.25	30.66	31.08	31.50	31.92	32.33
	11/32	32.24	32.70	33.16	33.62	34.07	34.53	34.99	35.45
	⅜	35.04	35.54	36.05	36.55	37.05	37.55	38.05	38.55
	7/16	40.59	41.18	41.76	42.35	42.93	43.51	44.10	44.68
	½	46.06	46.73	47.39	48.06	48.73	49.40	50.06	50.73
	9/16	51.44	52.19	52.94	53.69	54.44	55.19	55.95	56.70
	⅝	56.74	57.57	58.41	59.24	60.08	60.91	61.74	62.58
	11/16	61.95	62.87	63.79	64.71	65.62	66.54	67.46	68.38
	¾	67.08	68.09	69.09	70.09	71.09	72.09	73.09	74.09
	13/16	72.13	73.22	74.30	75.39	76.47	77.56	78.64	79.73
	⅞	77.10	78.27	79.43	80.60	81.77	82.94	84.11	85.27
	15/16	81.98	83.23	84.48	85.73	86.98	88.24	89.49	90.74
	1	86.78	88.11	89.45	90.78	92.12	93.45	94.79	96.12
	1 1/16	91.49	92.91	94.33	95.75	97.16	98.58	100.0	101.4
	1⅛	96.12	97.62	99.13	100.6	102.1	103.6	105.1	106.6
	1 3/16	100.7	102.3	103.8	105.4	107.0	108.6	110.2	111.8
	1¼	105.1	106.8	108.5	110.1	111.8	113.5	115.1	116.8
	1 5/16	109.5	111.3	113.0	114.8	116.5	118.3	120.0	121.8
	1⅜	113.8	115.6	117.5	119.3	121.2	123.0	124.8	126.7
	1 7/16	118.0	119.9	121.9	123.8	125.7	127.6	129.5	131.5
	1½	122.2	124.2	126.2	128.2	130.2	132.2	134.2	136.2

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	10⅛	10¼	10⅜	10½	10⅝	10¾	10⅞	11
	3/16	19.90	20.15	20.40	20.65	20.90	21.15	21.40	21.65
6	....	21.51	21.78	22.05	22.32	22.60	22.87	23.14	23.41
	7/32	23.14	23.44	23.73	24.02	24.31	24.60	24.90	25.19
5	....	23.27	23.57	23.86	24.15	24.45	24.74	25.04	25.33
4	....	25.13	25.45	25.77	26.08	26.40	26.72	27.04	27.36
	1/4	26.37	26.70	27.03	27.37	27.70	28.04	28.37	28.70
3	....	27.29	27.64	27.98	28.33	28.67	29.02	29.37	29.71
	9/32	29.57	29.94	30.32	30.70	31.07	31.45	31.82	32.20
2	....	29.85	30.23	30.61	30.99	31.37	31.75	32.12	32.50
1	....	31.48	31.88	32.28	32.68	33.08	33.48	33.88	34.28
	5/16	32.75	33.17	33.58	34.00	34.42	34.84	35.25	35.67
	11/32	35.91	36.37	36.83	37.29	37.75	38.20	38.66	39.12
	3/8	39.05	39.55	40.05	40.55	41.05	41.55	42.05	42.55
	7/16	45.27	45.85	46.43	47.02	47.60	48.19	48.77	49.35
	1/2	51.40	52.07	52.73	53.40	54.07	54.74	55.40	56.07
	9/16	57.45	58.20	58.95	59.70	60.45	61.20	61.95	62.70
	5/8	63.41	64.25	65.08	65.92	66.75	67.59	68.42	69.25
	11/16	69.30	70.21	71.13	72.05	72.97	73.88	74.80	75.72
	3/4	75.09	76.10	77.10	78.10	79.10	80.10	81.10	82.10
	13/16	80.81	81.90	82.98	84.06	85.15	86.23	87.32	88.40
	7/8	86.44	87.61	88.78	89.95	91.12	92.28	93.45	94.62
	15/16	91.99	93.24	94.49	95.75	97.00	98.25	99.50	100.8
	1	97.46	98.79	100.1	101.5	102.8	104.1	105.5	106.8
	1 1/16	102.8	104.3	105.7	107.1	108.5	109.9	111.3	112.8
	1 1/8	108.1	109.6	111.1	112.6	114.1	115.6	117.1	118.6
	1 3/16	113.4	114.9	116.5	118.1	119.7	121.3	122.9	124.4
	1 1/4	118.5	120.2	121.8	123.5	125.2	126.8	128.5	130.2
	1 5/16	123.5	125.3	127.0	128.8	130.5	132.3	134.0	135.8
	1 3/8	128.5	130.3	132.2	134.0	135.8	137.7	139.5	141.3
	1 7/16	133.4	135.3	137.2	139.1	141.1	143.0	144.9	146.8
	1 1/2	138.2	140.2	142.2	144.2	146.2	148.2	150.2	152.2

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	11 1/8	11 1/4	11 3/8	11 1/2	11 5/8	11 3/4	11 7/8	12
	3/16	21.90	22.15	22.40	22.65	22.90	23.15	23.40	23.65
6	....	23.68	23.95	24.22	24.49	24.76	25.03	25.31	25.58
	7/32	25.48	25.77	26.06	26.36	26.65	26.94	27.23	27.52
5	....	25.62	25.92	26.21	26.50	26.80	27.09	27.38	27.68
4	....	27.67	27.99	28.31	28.63	28.94	20.26	29.58	29.90
	1/4	29.04	29.37	29.70	30.04	30.37	30.71	31.04	31.37
3	....	30.06	30.40	30.75	31.09	31.44	31.79	32.13	32.48
	9/32	32.57	32.95	33.32	33.70	34.07	34.45	34.83	35.20
2	....	32.88	33.26	33.64	34.02	34.40	34.78	35.16	35.54
1	......	34.68	35.08	35.48	35.89	36.29	36.69	37.09	37.49
	5/16	36.09	36.50	36.92	37.34	37.76	38.17	38.59	39.01
	11/32	39.58	40.04	40.50	40.96	41.42	41.88	42.33	42.79
	3/8	43.05	43.56	44.06	44.56	45.06	45.56	46.06	46.56
	7/16	49.94	50.52	51.11	51.69	52.27	52.86	53.44	54.03
	1/2	56.74	57.41	58.07	58.74	59.41	60.08	60.74	61.41
	9/16	63.46	64.21	64.96	65.71	66.46	67.21	67.96	68.71
	5/8	70.09	70.92	71.76	72.59	73.43	74.26	75.09	75.93
	11/16	76.64	77.56	78.47	79.39	80.31	81.23	82.15	83.06
	3/4	83.10	84.11	85.11	86.11	87.11	88.11	89.11	90.11
	13/16	89.49	90.57	91.66	92.74	93.83	94.91	96.00	97.08
	7/8	95.79	96.96	98.12	99.29	100.5	101.6	102.8	104.0
	15/16	102.0	103.3	104.5	105.8	107.0	108.3	109.5	110.8
	1	108.1	109.5	110.8	112.1	113.5	114.8	116.1	117.5
	1 1/16	114.2	115.6	117.0	118.4	119.9	121.3	122.7	124.1
	1 1/8	120.2	121.7	123.2	124.7	126.2	127.7	129.2	130.7
	1 3/16	126.0	127.6	129.2	130.8	132.4	134.0	135.5	137.1
	1 1/4	131.8	133.5	135.2	136.8	138.5	140.2	141.8	143.5
	1 5/16	137.5	139.3	141.1	142.8	144.6	146.3	148.1	149.8
	1 3/8	143.2	145.0	146.9	148.7	150.5	152.4	154.2	156.0
	1 7/16	148.7	150.6	152.6	154.5	156.4	158.3	160.2	162.2
	1 1/2	154.2	156.2	158.2	160.2	162.2	164.2	166.2	168.2

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	12⅛	12¼	12⅜	12½	12⅝	12¾	12⅞	13
	3/16	23.91	24.16	24.41	24.66	24.91	25.16	25.41	25.66
6	....	25.85	26.12	26.39	26.66	26.93	27.20	27.47	27.74
	7/32	27.82	28.11	28.40	28.69	28.98	29.28	29.57	29.86
5	....	27.97	28.27	28.56	28.85	29.15	29.44	29.73	30.03
4	....	30.22	30.53	30.85	31.17	31.49	31.80	32.12	32.44
	¼	31.71	32.04	32.37	32.71	33.04	33.38	33.71	34.04
3	....	32.82	33.17	33.51	33.86	34.21	34.55	34.90	35.24
	9/32	35.58	35.95	36.33	36.70	37.08	37.45	37.83	38.20
2	....	35.92	36.29	36.67	37.05	37.43	37.81	38.19	38.57
1	....	37.89	38.29	38.69	39.09	39.49	39.89	40.29	40.69
	5/16	39.42	39.84	40.26	40.68	41.09	41.51	41.93	42.35
	11/32	43.25	43.71	44.17	44.63	45.09	45.55	46.01	46.46
	⅜	47.06	47.56	48.06	48.56	49.06	49.56	50.06	50.56
	7/16	54.61	55.19	55.78	56.36	56.95	57.53	58.12	58.70
	½	62.08	62.75	63.41	64.08	64.75	65.42	66.08	66.75
	9/16	69.46	70.21	70.96	71.72	72.47	73.22	73.97	74.73
	⅝	76.76	77.60	78.43	79.27	80.10	80.94	81.77	82.60
	11/16	83.98	84.90	85.82	86.73	87.65	88.57	89.49	90.41
	¾	91.12	92.12	93.12	94.12	95.12	96.12	97.12	98.12
	13/16	98.17	99.25	100.3	101.4	102.5	103.6	104.7	105.8
	⅞	105.1	106.3	107.5	108.6	109.8	111.0	112.1	113.3
	15/16	112.0	113.3	114.5	115.8	117.0	118.3	119.5	120.8
	1	118.8	120.2	121.5	122.8	124.2	125.5	126.8	128.2
	1 1/16	125.5	127.0	128.4	129.8	131.2	132.6	134.0	135.5
	1⅛	132.2	133.7	135.2	136.7	138.2	139.7	141.2	142.7
	1 3/16	138.7	140.3	141.9	143.5	145.1	146.6	148.2	149.8
	1¼	145.2	146.9	148.5	150.2	151.9	153.5	155.2	156.9
	1 5/16	151.6	153.3	155.1	156.8	158.6	160.3	162.1	163.8
	1⅜	157.9	159.7	161.5	163.4	165.2	167.0	168.9	170.7
	1 7/16	164.1	166.0	167.9	169.8	171.8	173.7	175.6	177.5
	1½	170.2	172.2	174.2	176.2	178.2	180.2	182.2	184.2

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	13⅛	13¼	13⅜	13½	13⅝	13¾	13⅞	14
	3/16	25.91	26.16	26.41	26.66	26.91	27.16	27.41	27.66
6	....	28.02	28.29	28.56	28.83	29.10	29.37	29.64	29.91
	7/32	30.15	30.44	30.74	31.03	31.32	31.61	31.90	32.20
5	....	30.32	30.62	30.91	31.20	31.50	31.79	32.08	32.38
4	....	32.76	33.07	33.39	33.71	34.03	34.35	34.66	34.98
	¼	34.38	34.71	35.04	35.38	35.71	36.05	36.38	36.71
3	....	35.59	35.94	36.28	36.63	36.97	37.32	37.66	38.01
	9/32	38.58	38.96	39.33	39.71	40.08	40.46	40.83	41.21
2	....	38.95	39.33	39.71	40.09	40.47	40.84	41.22	41.60
1	....	41.09	41.49	41.89	42.29	42.69	43.09	43.49	43.90
	5/16	42.76	43.18	43.60	44.01	44.43	44.85	45.27	45.68
	11/32	46.92	47.38	47.84	48.30	48.76	49.22	49.68	50.14
	⅜	51.06	51.57	52.07	52.57	53.07	53.57	54.07	54.57
	7/16	59.28	59.87	60.45	61.04	61.62	62.20	62.79	63.37
	½	67.42	68.09	68.75	69.42	70.09	70.76	71.42	72.09
	9/16	75.47	76.22	76.97	77.72	78.47	79.23	79.98	80.73
	⅝	83.44	84.27	85.11	85.94	86.78	87.61	88.45	89.28
	11/16	91.32	92.24	93.16	94.08	94.99	95.91	96.83	97.75
	¾	99.13	100.1	101.1	102.1	103.1	104.1	105.1	106.1
	13/16	106.8	107.9	100.0	110.1	111.2	112.3	113.4	114.4
	⅞	114.5	115.6	116.8	118.0	119.2	120.3	121.5	122.7
	15/16	122.0	123.3	124.5	125.8	127.0	128.3	129.5	130.8
	1	129.5	130.8	132.2	133.5	134.8	136.2	137.5	138.8
	1 1/16	136.9	138.3	139.7	141.1	142.6	144.0	145.4	146.8
	1⅛	144.2	145.7	147.2	148.7	150.2	151.7	153.2	154.7
	1 3/16	151.4	153.0	154.6	156.2	157.7	159.3	160.9	162.5
	1¼	158.5	160.2	161.9	163.5	165.2	166.9	168.5	170.2
	1 5/16	165.6	167.3	169.1	170.8	172.6	174.3	176.1	177.8
	1⅜	172.6	174.4	176.2	178.1	179.9	181.7	183.6	185.4
	1 7/16	179.4	181.4	183.3	185.2	187.1	189.0	190.9	192.9
	1½	186.2	188.2	190.2	192.2	194.2	196.2	198.3	200.3

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	14⅛	14¼	14⅜	14½	14⅝	14¾	14⅞	15
	3/16	27.91	28.16	28.41	28.66	28.91	29.16	29.41	29.66
6	....	30.18	30.45	30.73	31.00	31.27	31.54	31.81	32.08
	7/32	32.49	32.78	33.07	33.37	33.66	33.95	34.24	34.53
5	....	32.67	32.97	33.26	33.55	33.85	34.14	34.43	34.73
4	....	35.30	35.62	35.93	36.25	36.57	36.89	37.21	37.52
	¼	37.05	37.38	37.71	38.05	38.38	38.72	39.05	39.38
3	....	38.36	38.70	39.05	39.39	39.74	40.08	40.43	40.78
	9/32	41.58	41.96	42.33	42.71	43.09	43.46	43.84	44.21
2	....	41.98	42.36	42.74	43.12	43.50	43.88	44.26	44.64
1	....	44.30	44.70	45.10	45.50	45.90	46.30	46.70	47.10
	5/16	46.10	46.52	46.93	47.35	47.77	48.19	48.60	49.02
	11/32	50.60	51.05	51.51	51.97	52.43	52.89	53.35	53.81
	⅜	55.07	55.57	56.07	56.57	57.07	57 57	58.07	58.57
	7/16	63.96	64.54	65.12	65.71	66.29	66.88	67.46	68.04
	½	72.76	73.43	74.09	74.76	75.43	76.10	76.76	77.43
	9/16	81.48	82.23	82.98	83.73	84.48	85.23	85.98	86.73
	⅝	90.11	90.95	91.78	92.62	93.45	94.29	95.12	95.95
	11/16	98.67	99.58	100.5	101.4	102.3	103.3	104.2	105.1
	¾	107.1	108.1	109.1	110.1	111.1	112.1	113.1	114.1
	13/16	115.5	116.6	117.7	118.8	119.9	120.9	122.0	123.1
	⅞	123.8	125.0	126.2	127.3	128.5	129.7	130.8	132.0
	15/16	132.0	133.3	134.5	135.8	137.0	138.3	139.6	140.8
	1	140.2	141.5	142.8	144.2	145.5	146.9	148.2	149.5
	1 1/16	148.2	149.6	151.1	152.5	153.9	155.3	156.7	158.2
	1⅛	156.2	157.7	159.2	160.7	162.2	163.7	165.2	166.7
	1 3/16	164.1	165.7	167.3	168.8	170.4	172.0	173.6	175.2
	1¼	171.9	173.6	175.2	176.9	178.6	180.2	181.9	183.6
	1 5/16	179.6	181.4	183.1	184.9	186.6	188.4	190.1	191.9
	1⅜	187.2	189.1	190.9	192.7	194.6	196.4	198.3	200.1
	1 7/16	194.8	196.7	198.6	200.5	202.5	204.4	206.3	208.2
	1½	202.3	204.3	206.3	208.3	210.3	212.3	214.3	216.3

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	15⅛	15¼	15⅜	15½	15⅝	15¾	15⅞	16
	3/16	29.91	30.16	30.41	30.66	30.91	31.16	31.41	31.66
6	....	32.35	32.62	32.89	33.16	33.44	33.71	33.98	34.25
	7/32	34.83	35.12	35.41	35.70	35.99	36.29	36.58	36.87
5	....	35.02	35.32	35.61	35.90	36.20	36.49	36.78	37.08
4	....	37.84	38.16	38.48	38.79	39.11	39.43	39.75	40.07
	¼	39.72	40.05	40.38	40.72	41.05	41.39	41.72	42.05
3	....	41.12	41.47	41.81	42.16	42.50	42.85	43.20	43.54
	9/32	44.59	44.96	45.34	45.71	46.09	46.46	46.84	47.22
2	....	45.02	45.39	45.77	46.15	46.53	46.91	47.29	47.67
1	....	47.50	47.90	48.30	48.70	49.10	49.50	49.90	50.30
	5/16	49.44	49.85	50.27	50.69	51.11	51.52	51.94	52.36
	11/32	54.27	54.73	55.18	55.64	56.10	56.56	57.02	57.48
	⅜	59.07	59.58	60.08	60.58	61.08	61.58	62.08	62.58
	7/16	68.63	69.21	69.80	70.38	70.96	71.55	72.13	72.72
	½	78.10	78.77	79.43	80.10	80.77	81.44	82.10	82.77
	9/16	87.49	88.24	88.99	89.74	90.49	91.24	91.99	92.74
	⅝	96.79	97.62	98.46	99.29	100.1	101.0	101.8	102.6
	11/16	106.0	107.0	107.8	108.8	109.7	110.6	111.5	112.4
	¾	115.1	116.1	117.1	118.1	119.2	120.2	121.2	122.2
	13/16	124.2	125.3	126.4	127.5	128.5	129.6	130.7	131.8
	⅞	133.2	134.3	135.5	136.7	137.8	139.0	140.2	141.3
	15/16	142.1	143.3	144.6	145.8	147.1	148.3	149.6	150.8
	1	150.9	152.2	153.5	154.9	156.2	157.5	158.9	160.2
	1 1/16	159.6	161.0	162.4	163.8	165.3	166.7	168.1	169.5
	1⅛	168.2	169.7	171.2	172.7	174.2	175.7	177.2	178.7
	1 3/16	176.8	178.4	179.9	181.5	183.1	184.7	186.3	187.9
	1¼	185.2	186.9	188.6	190.2	191.9	193.6	195.2	196.9
	1 5/16	193.6	195.4	197.1	198.9	200.6	202.4	204.1	205.9
	1⅜	201.9	203.8	205.6	207.4	209.3	211.1	212.9	214.8
	1 7/16	210.1	212.1	214.0	215.9	217.8	219.7	221.7	223.6
	1½	218.3	220.3	222.3	224.3	226.3	228.3	230.3	232.3

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	16⅛	16¼	16⅜	16½	16⅝	16¾	16⅞	17
	3/16	31.92	32.17	32.42	32.67	32.92	33.17	33.42	33.67
6	....	34.52	34.79	35.06	35.33	35.60	35.88	36.15	36.42
	7/32	37.16	37.45	37.75	38.04	38.33	38.62	38.91	39.21
5	....	37.37	37.66	37.96	38.25	38.55	38.84	39.13	39.43
4	....	40.38	40.70	41.02	41.34	41.65	41.97	42.29	42.61
	1/4	42.39	42.72	43.05	43.39	43.72	44.06	44.39	44.72
3	....	43.89	44.23	44.58	44.93	45.27	45.62	45.96	46.31
	9/32	47.59	47.97	48.34	48.72	49.09	49.47	49.84	50.22
2	....	48.05	48.43	48.81	49.19	49.56	49.94	50.32	50.70
1	....	50.70	51.10	51.51	51.91	52.31	52.71	53.11	53.51
	5/16	52.77	53.19	53.61	54.03	54.44	54.86	55.28	55.70
	11/32	57.94	58.40	58.86	59.31	59.77	60.23	60.69	61.15
	3/8	63.08	63.58	64.08	64.58	65.08	65.58	66.08	66.58
	7/16	73.30	73.88	74.47	75.05	75.64	76.22	76.81	77.39
	1/2	83.44	84.11	84.77	85.44	86.11	86.78	87.44	88.11
	9/16	93.49	94.24	95.00	95.75	96.50	97.25	98.00	98.75
	5/8	103.5	104.3	105.1	106.0	106.8	107.6	108.5	109.3
	11/16	113.4	114.3	115.2	116.1	117.0	117.9	118.9	119.8
	3/4	123.2	124.2	125.2	126.2	127.2	128.2	129.2	130.2
	13/16	132.9	134.0	135.0	136.1	137.2	138.3	139.4	140.5
	7/8	142.5	143.7	144 8	146.0	147.2	148.4	149.5	150.7
	15/16	152.1	153.3	154.6	155.8	157.1	158.3	159.6	160.8
	1	161.5	162.9	164.2	165.5	166.9	168.2	169.5	170.9
	1 1/16	170.9	172.3	173.8	175.2	176.6	178.0	179.4	180.9
	1⅛	180.2	181.7	183.2	184.7	186.2	187.7	189.2	190.7
	1 3/16	189.4	191.0	192.6	194.2	195.8	197.4	199.0	200.5
	1¼	198.6	200.3	201.9	203.6	205.3	206.9	208.6	210.3
	1 5/16	207.6	209.4	211.1	212.9	214.6	216.4	218.2	219.9
	1⅜	216.6	218.4	220.3	222.1	223.9	225.8	227.6	229.5
	1 7/16	225.5	227.4	229.3	231.3	233.2	235.1	237.0	238.9
	1½	234.3	236.3	238.3	240.3	242.3	244.3	246.3	248.3

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	17⅛	17¼	17⅜	17½	17⅝	17¾	17⅞	18
	3/16	33.92	34.17	34.42	34.67	34.92	35.17	35.42	35.67
6	....	36.69	36.96	37.23	37.50	37.77	38.04	38.31	38.59
	7/32	39.50	39.79	40.08	40.37	40.67	40.96	41.25	41.54
5	....	39.72	40.01	40.31	40.60	40.90	41.19	41.48	41.78
4	....	42.92	43.24	43.56	43.88	44.20	44.51	44.83	45.15
	¼	45.06	45.39	45.72	46.06	46.39	46.73	47.06	47.39
3	....	46.65	47.00	47.35	47.69	48.04	48.38	48.73	49.07
	9/32	50.60	50.97	51.35	51.72	52.10	52.47	52.85	53.22
2	....	51.08	51.46	51.84	52.22	52.60	52.98	53.36	53.74
1	....	53.91	54.31	54.71	55.11	55.51	55.91	56.31	56.71
	5/16	56.11	56.53	56.95	57.36	57.78	58.20	58.62	59.03
	11/32	61.61	62.07	62.53	62.99	63.44	63.90	64.36	64.82
	⅜	67.08	67.59	68.09	68.59	69.09	69.59	70.09	70.59
	7/16	77.97	78.56	79.14	79.73	80.31	80.89	81.48	82.06
	½	88.78	89.45	90.11	90.78	91.45	92.12	92.78	93.45
	9/16	99.50	100.3	101.0	101.8	102.5	103.3	104.0	104.8
	⅝	110.1	111.0	111.8	112.6	113.5	114.3	115.1	116.0
	11/16	120.7	121.6	122.5	123.4	124.4	125.3	126.2	127.1
	¾	131.2	132.2	133.2	134.2	135.2	136.2	137.2	138.2
	13/16	141.6	142.6	143.7	144.8	145.9	147.0	148.1	149.1
	⅞	151.9	153.0	154.2	155.4	156.5	157.7	158.9	160.0
	15/16	162.1	163.3	164.6	165.8	167.1	168.3	169.6	170.8
	1	172.2	173.6	174.9	176.2	177.6	178.9	180.2	181.6
	1 1/16	182.3	183.7	185.1	186.5	187.9	189.4	190.8	192.2
	1⅛	192.2	193.7	195.2	196.7	198.3	199.8	201.3	202.8
	1 3/16	202.1	203.7	205.3	206.9	208.5	210.1	211.6	213.2
	1¼	211.9	213.6	215.3	216.9	218.6	220.3	221.9	223.6
	1 5/16	221.7	223.4	225.2	226.9	228.7	230.4	232.2	233.9
	1⅜	231.3	233.1	235.0	236.8	238.6	240.5	242.3	244.1
	1 7/16	240.8	242.8	244.7	246.6	248.5	250.4	252.4	254.3
	1½	250.3	252.3	254.3	256.3	258.3	260.3	262.3	264.3

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	18⅛	18¼	18⅜	18½	18⅝	18¾	18⅞	19
	3/16	35.92	36.17	36.42	36.67	36.92	37.17	37.42	37.67
6	....	38.86	39.13	39.40	39.67	39.94	40.21	40.48	40.75
	7/32	41.83	42.13	42.42	42.71	43.00	43.29	43.59	43.88
5	....	42.07	42.36	42.66	42.95	43.25	43.54	43.83	44.13
4	....	45.47	45.78	46.10	46.42	46.74	47.06	47.37	47.69
	¼	47.73	48.06	48.39	48.73	49.06	49.40	49.73	50.06
3	....	49.42	49.77	50.11	50.46	50.80	51.15	51.49	51.84
	9/32	53.60	53.97	54.35	54.73	55.10	55.48	55.85	56.23
2	....	54.11	54.49	54.87	55.25	55.63	56.01	56.39	56.77
1	....	57.11	57.51	57.91	58.31	58.71	59.11	59.52	59.92
	5/16	59.45	59.87	60.28	60.70	61.12	61.54	61.95	62.37
	11/32	65.28	65.74	66.20	66.66	67.12	67.57	68.03	68.49
	⅜	71.09	71.59	72.09	72.59	73.09	73.59	74.09	74.59
	7/16	82.65	83.23	83.81	84.40	84.98	85.57	86.15	86.73
	½	94.12	94.79	95.45	96.12	96.79	97.46	98.12	98.79
	9/16	105.5	106.3	107.0	107.8	108.5	109.3	110.0	110.8
	⅝	116.8	117.6	118.5	119.3	120.2	121.0	121.8	122.7
	11/16	128.0	129.0	129.9	130.8	131.7	132.6	133.5	134.5
	¾	139.2	140.2	141.2	142.2	143.2	144.2	145.2	146.2
	13/16	150.2	151.3	152.4	153.5	154.6	155.7	156.7	157.8
	⅞	161.2	162.4	163.5	164.7	165.9	167.0	168.2	169.4
	15/16	172.1	173.3	174.6	175.8	177.1	178.4	179.6	180.9
	1	182.9	184.2	185.6	186.9	188.2	189.6	190.9	192.2
	1 1/16	193.6	195.1	196.5	197.9	199.3	200.7	202.1	203.5
	1⅛	204.3	205.8	207.3	208.8	210.3	211.8	213.3	214.8
	1 3/16	214.8	216.4	218.0	219.6	221.2	222.7	224.3	225.9
	1¼	225.3	227.0	228.6	230.3	232.0	233.6	235.3	237.0
	1 5/16	235.7	237.4	239.2	240.9	242.7	244.4	246.2	247.9
	1⅜	246.0	247.8	249.6	251.5	253.3	255.2	257.0	258.8
	1 7/16	256.2	258.1	260.0	262.0	263.9	265.8	267.7	269.6
	1½	266.3	268.3	270.3	272.3	274.3	276.3	278.4	280.4

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	19⅛	19¼	19⅜	19½	19⅝	19¾	19⅞	20
	3/16	37.92	38.17	38.42	38.67	38.92	39.17	39.43	39.68
6	....	41.02	41.30	41.57	41.84	42.11	42.38	42.65	42.92
	7/32	44.17	44.46	44.75	45.05	45.34	45.63	45.92	46.21
5	....	44.42	44.71	45.01	45.30	45.59	45.89	46.18	46.48
4	....	48.01	48.33	48.64	48.96	49.28	49.60	49.91	50.23
	¼	50.40	50.73	51.06	51.40	51.73	52.07	52.40	52.73
3	....	52.19	52.53	52.88	53.22	53.57	53.92	54.26	5[illegible].61
	9/32	56.60	56.98	57.35	57.73	58.10	58.48	58.86	5[illegible]23
2	....	57.15	57.53	57.91	58.29	58.66	59.04	59.42	5[illegible]60
1	....	60.32	60.72	61.12	61.52	61.92	62.32	62.72	63.12
	5/16	62.79	63.20	63.62	64.04	64.46	64.87	65.29	65.71
	11/32	68.95	69.41	69.87	70.33	70.79	71.25	71.71	72.16
	⅜	75.09	75.60	76.10	76.60	77.10	77.60	78.10	78.60
	7/16	87.32	87.90	88.49	89.07	89.65	90.24	90.82	91.41
	½	99.46	100.1	100.8	101.5	102.1	102.8	102.5	104.1
	9/16	111.5	112.3	113.0	113.8	114.5	115.3	116.0	116.8
	⅝	123.5	124.3	125.2	126.0	126.8	127.7	128.5	129.3
	11/16	135.4	136.3	137.2	138.1	139.1	140.0	140.9	141.8
	¾	147.2	148.2	149.2	150.2	151.2	152.2	153.2	154.2
	13/16	158.9	160.0	161.1	162.2	163.2	164.3	165.4	166.5
	⅞	170.5	171.7	172.9	174.1	175.2	176.4	175.6	178.7
	15/16	182.1	183.4	184.6	185.9	187.1	188.4	189.6	190.9
	1	193.6	194.9	196.2	197.6	198.9	200.3	201.6	202.9
	1 1/16	205.0	206.4	207.8	209.2	210.6	212.1	213.5	214.9
	1⅛	216.3	217.8	219.3	220.8	222.3	223.8	225.3	226.8
	1 3/16	227.5	229.1	230.7	232.3	233.8	235.4	237.0	238.6
	1¼	238.6	240.3	242.0	243.6	245.3	247.0	248.6	250.3
	1 5/16	249.7	251.4	253.2	254.9	256.7	258.5	260.2	262.0
	1⅜	260.7	262.5	264.3	266.2	268.0	269.8	271.7	273.5
	1 7/16	271.6	273.5	275.4	277.3	279.2	281.1	283.1	285.0
	1½	282.4	284.4	286.4	288.4	290.4	292.4	294.4	296.4

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	20⅛	20¼	20⅜	20½	20⅝	20¾	20⅞	21
	3/16	39.93	40.18	40.43	40.68	40.93	41.18	41.43	41.68
6	....	43.19	43.46	43.73	44.01	44.28	44.55	44.82	45.09
	7/32	46.51	46.80	47.09	47.38	47.67	47.97	48.26	48.55
5	....	46.77	47.06	47.36	47.65	47.94	48.24	48.53	48.83
4	....	50.55	50.87	51.19	51.50	51.82	52.14	52.46	52.77
	¼	53.07	53.40	53.73	54.07	54.40	54.74	55.07	55.40
3	....	54.95	55.30	55.64	55.99	56.34	56.68	57.03	57.37
	9/32	59.61	59.98	60.36	60.73	61.11	61.48	61.86	62.23
2	....	60.18	60.56	60.94	61.32	61.70	62.08	62.46	62.84
1	....	63.52	63.92	64.32	64.72	65.12	65.52	65.92	66.32
	5/16	66.13	66.54	66.96	67.38	67.79	68.21	68.63	69.05
	11/32	72.62	73.08	73.54	74.00	74.46	74.92	75.38	75.84
	⅜	79.10	79.60	80.10	80.60	81.10	81.60	82.10	82.60
	7/16	91.99	92.58	93.16	93.74	94.33	94.91	95.50	96.08
	½	104.8	105.5	106.1	106.8	107.5	108.1	108.8	109.5
	9/16	117.5	118.3	119.0	119.8	120.5	121.3	122.0	122.8
	⅝	130.2	131.0	131.8	132.7	133.5	134.3	135.2	136.0
	11/16	142.7	143.6	144.6	145.5	146.4	147.3	148.2	149.1
	¾	155.2	156.2	157.2	158.2	159.2	160.2	161.2	162.2
	13/16	167.6	168.7	169.8	170.8	171.9	173.0	174.1	175.2
	⅞	179.9	181.1	182.2	183.4	184.6	185.7	186.9	188.1
	15/16	192.1	193.4	194.6	195.9	197.1	198.4	199.6	200.9
	1	204.3	205.6	206.9	208.3	209.6	210.9	212.3	213.6
	1 1/16	216.3	217.7	219.2	220.6	222.0	223.4	224.8	226.2
	1⅛	228.3	229.8	231.3	232.8	234.3	235.8	237.3	238.8
	1 3/16	240.2	241.8	243 3	244.9	246.5	248.1	249.7	251.3
	1¼	252.0	253.7	255.3	257.0	258.7	260.3	262.0	263.7
	1 5/16	263.7	265.5	267.2	269.0	270.7	272.5	274.2	276.0
	1⅜	275.3	277.2	279.0	280.9	282.7	284.5	286.4	288.2
	1 7/16	286.9	288.8	290.7	292.7	294.6	296.5	298.4	300.3
	1½	298.4	300.4	302.4	304.4	306 4	308.4	310.4	312.4

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	21⅛	21¼	21⅜	21½	21⅝	21¾	21⅞	22
	3/16	41.93	42.18	42.43	42.68	42.93	43.18	43.43	43.68
6	....	45.36	45.63	45.90	46.17	46.44	46.72	46.99	47.26
	7/32	48.84	49.13	49.43	49.72	50.01	50.30	50.60	50.89
5	....	49.12	49.41	49.71	50.00	50.29	50.59	50.88	51.18
4	....	53.09	53.41	53.73	54.05	54.36	54.68	55.00	55.32
	¼	55.74	56.07	56.40	56.74	57.07	57.41	57.74	58.07
3	....	57.72	58.06	58.41	58.76	59.10	59.45	59.79	60.14
	9/32	62.61	62.99	63.36	63.74	64.11	64.49	64.86	65.24
2	....	63.21	63.59	63.97	64.35	64.73	65.11	65.49	65.87
1	....	66.72	67.12	67.53	67.93	68.33	68.73	69.13	69.53
	5/16	69.46	69.88	70.30	70.71	71.13	71.55	71.97	72.38
	11/32	76.29	76.75	77.21	77.67	78.13	78.59	79.05	79.51
	⅜	83.10	83.61	84.11	84.61	85.11	85.61	86.11	86.61
	7/16	96.66	97.25	97.83	98.42	99.0	99.58	100.2	100.8
	½	110.1	110.8	111.5	112.1	112.8	113.5	114.1	114.8
	9/16	123.5	124.3	125.0	125.8	126.5	127.3	128.0	128.8
	⅝	136.8	137.7	138.5	139.3	140.2	141.0	141.8	142.7
	11/16	150.1	151.0	151.9	152.8	153.7	154.7	155.6	156.5
	¾	163.2	164.2	165.2	166.2	167.2	168.2	169.2	170.2
	13/16	176.3	177.3	178.4	179.5	180.6	181.7	182.8	183.9
	⅞	189.2	190.4	191.6	192.7	193.9	195.1	196.2	197.4
	15/16	202.1	203.4	204.6	205.9	207.1	208.4	209.6	210.9
	1	214.9	216.3	217.6	218.9	220.3	221.6	222.9	224.3
	1 1/16	227.7	229.1	230.5	231.9	233.3	234.8	236.2	237.6
	1⅛	240.3	241.8	243.3	244.8	246.3	247.8	249.3	250.8
	1 3/16	252.9	254.4	256.0	257.6	259.2	260.8	262.4	264.0
	1¼	265.3	267.0	268.7	270.3	272.0	273.7	275.3	277.0
	1 5/16	277.7	279.5	281.2	283.0	284.7	286.5	288.2	290.0
	1⅜	290.0	291.9	293.7	295.5	297.4	299.2	301.0	302.9
	1 7/16	302.3	304.2	306.1	308.0	309.9	311.9	313.8	315.7
	1½	314.4	316.4	318.4	320.4	322.4	324.4	326.4	328.4

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	22⅛	22¼	22⅜	22½	22⅝	22¾	22⅞	23
	3/16	43.93	44.18	44.43	44.68	44.93	45.18	45.43	45.68
6	....	47.53	47.80	48.07	48.34	48.61	48.88	49.15	49.43
	7/32	51.18	51.47	51.76	52.06	52.35	52.64	52.93	53.22
5	......	51.47	51.76	52.06	52.35	52.64	52.94	53.23	53.52
4	....	55.63	55.95	56.27	56.59	56.91	57.22	57.54	57.86
	¼	58.41	58.74	59.07	59.41	59.74	60.08	60.41	60.74
3	....	60.48	60.83	61.18	61.52	61.87	62.21	62.56	62.91
	9/32	65.61	65.99	66.37	66.74	67.12	67.49	67.87	68.24
2	....	66.25	66.63	67.01	67.38	67.76	68.14	68.52	68.90
1	....	69.93	70.33	70.73	71.13	71.53	71.93	72.33	72.73
	5/16	72.80	73.22	73.63	74.05	74.47	74.89	75.30	75.72
	11/32	79.97	80.42	80.88	81.34	81.80	82.26	82.72	83.18
	⅜	87.11	87.61	88.11	88.61	89.11	89.61	90.11	90.61
	7/16	101.3	101.9	102.5	103.1	103.7	104.3	104.8	105.4
	½	115.5	116.1	116.8	117.5	118.1	118.8	119.5	120.2
	9/16	129.5	130.3	131.0	131.8	132.5	133.3	134.0	134.8
	⅝	143.5	144.3	145.2	146.0	146.9	147.7	148.5	149.4
	11/16	157.4	158.3	159.2	160.2	161.1	162.0	162.9	163.8
	¾	171.2	172.2	173.2	174.2	175.2	176.2	177.2	178.2
	13/16	184.9	186.0	187.1	188.2	189.3	190.4	191.5	192.5
	⅞	198.6	199.8	200.9	202.1	203.3	204.4	205.6	206.8
	15/16	212.1	213.4	214.6	215.9	217.1	218.4	219.7	220.9
	1	225.6	227.0	228.3	229.6	231.0	232.3	233.6	235.0
	1 1/16	239.0	240.4	241.8	243.3	244.7	246.1	247.5	248.9
	1⅛	252.3	253.8	255.3	256.8	258.3	259.8	261.3	262.8
	1 3/16	265.5	267.1	268.7	270.3	271.9	273.5	275.1	276.6
	1¼	278.7	280.4	282.0	283.7	285.4	287.0	288.7	290.4
	1 5/16	291.7	293.5	295.2	297.0	298.8	300.5	302.3	304.0
	1⅜	304.7	306.6	308.4	310.2	312.1	313.9	315.7	317.6
	1 7/16	317.6	319.5	321.4	323.4	325.3	327.2	329.1	331.0
	1½	330.4	332.4	334.4	336.4	338.4	340.4	342.4	344.4

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	23⅛	23¼	23⅜	23½	23⅝	23¾	23⅞	24
	3/16	45.93	46.18	46.43	46.68	46.93	47.18	47.43	47.69
6	....	49.70	49.97	50.24	50.51	50.78	51.05	51.32	51.59
	7/32	53.52	53.81	54.10	54.39	54.68	54.98	55.27	55.56
5	....	53.82	54.11	54.41	54.70	54.99	55.29	55.58	55.87
4	....	58.18	58.49	58.81	59.13	59.45	59.76	60.08	60.40
	¼	61.08	61.41	61.74	62.08	62.41	62.75	63.08	63.41
3	....	63.25	63.60	63.94	64.29	64.63	64.98	65.33	65.67
	9/32	68.62	68.99	69.37	69.74	70.12	70.50	70.87	71.25
2	....	69.28	69.66	70.04	70.42	70.80	71.18	71.56	71.93
1	....	73.13	73.53	73.93	74.33	74.73	75.13	75.54	75.94
	5/16	76.14	76.56	76.97	77.39	77.81	78.22	78.64	79.06
	11/32	83.64	84.10	84.55	85.01	85.47	85.93	86.39	86.85
	⅜	91.12	91.62	92.12	92.62	93.12	93.62	94.12	94.62
	7/16	106.0	106.6	107.2	107.8	108.3	108.9	109.5	110.1
	½	120.8	121.5	122.2	122.8	123.5	124.2	124.8	125.5
	9/16	135.5	136.3	137.0	137.8	138.6	139.3	140.1	140.8
	⅝	150.2	151.0	151.9	152.7	153.5	154.4	155.2	156.0
	11/16	164.7	165.7	166.6	167.5	168.4	169.3	170.3	171.2
	¾	179.2	180.2	181.2	182.2	183.2	184.2	185.2	186.2
	13/16	193.6	194.7	195.8	196.9	198.0	199.0	200.1	201.2
	⅞	207.9	209.1	210.3	211.4	212.6	213.8	214.9	216.1
	15/16	222.2	223.4	224.7	225.9	227.2	228.4	229.7	230.9
	1	236.3	237.6	239.0	240.3	241.6	243.0	244.3	245.6
	1 1/16	250.4	251.8	253.2	254.6	256.0	257.5	258.9	260.3
	1⅛	264.3	265.8	267.3	268.8	270.3	271.8	273.3	274.8
	1 3/16	278.2	279.8	281.4	283.0	284.6	286.2	287.7	289.3
	1¼	292.0	293.7	295.4	297.0	298.7	300.4	302.0	303.7
	1 5/16	305.8	307.5	309.3	311.0	312.8	314.5	316.3	318.0
	1⅜	319.4	321.2	323.1	324.9	326.7	328.6	330.4	332.3
	1 7/16	333.0	334.9	336.8	338.7	340.6	342.6	344.5	346.4
	1½	346.4	348.4	350.4	352.4	354.4	356.5	358.5	360.5

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	24⅛	24¼	24⅜	24½	24⅝	24¾	24⅞	25
	3/16	47.94	48.19	48.44	48.69	48.94	49.19	49.44	49.69
6	....	51.86	52.14	52.41	52.68	52.95	53.22	53.49	53.76
	7/32	55.85	56.14	56.44	56.73	57.02	57.31	57.60	57.90
5	....	56.17	56.46	56.76	57.05	57.34	57.64	57.93	58.22
4	....	60.72	61.04	61.35	61.67	61.99	62.31	62.62	62.94
	¼	63.75	64.08	64.41	64.75	65.08	65.42	65.75	66.08
3	....	66.02	66.36	66.71	67.05	67.40	67.75	68.09	68.44
	9/32	71.62	72.00	72.37	72.75	73.12	73.50	73.87	74.25
2	....	72.31	72.69	73.07	73.45	73.83	74.21	74.59	74.97
1	....	76.34	76.74	77.14	77.54	77.94	78.34	78.74	79.14
	5/16	79.48	79.89	80.31	80.73	81.14	81.56	81.98	82.40
	11/32	87.31	87.77	88.23	88.68	89.14	89.60	90.06	90.52
	⅜	95.12	95.62	96.12	96.62	97.12	97.62	98.12	98.62
	7/16	110.7	111.3	111.8	112.4	113.0	113.6	114.2	114.8
	½	126.2	126.8	127.5	128.2	128.8	129.5	130.2	130.8
	9/16	141.6	142.3	143.1	143.8	144.6	145.3	146.1	146.8
	⅝	156.9	157.7	158.5	159.4	160.2	161.0	161.9	162.7
	11/16	172.1	173.0	173.9	174.8	175.8	176.7	177.6	178.5
	¾	187.2	188.2	189.2	190.2	191.2	192.2	193.2	194.2
	13/16	202.3	203.4	204.5	205.6	206.6	207.7	208.8	209.9
	⅞	217.3	218.4	219.6	220.8	221.9	223.1	224.3	225.5
	15/16	232.2	233.4	234.7	235.9	237.2	238.4	239.7	240.9
	1	247.0	248.3	249.6	251.0	252.3	253.7	255.0	256.3
	1 1/16	261.7	263.1	264.5	266.0	267.4	268.8	270.2	271.6
	1⅛	276.3	277.9	279.4	280.9	282.4	283.9	285.4	286.9
	1 3/16	290.9	292.5	294.1	295.7	297.3	298.8	300.4	302.0
	1¼	305.4	307.1	308.7	310.4	312.1	313.7	315.4	317.1
	1 5/16	319.8	321.5	323.3	325.0	326.8	328.5	330.3	332.0
	1⅜	334.1	335.9	337.8	339.6	341.4	343.3	345.1	346.9
	1 7/16	348.3	350.2	352.2	354.1	356.0	357.9	359.8	361.7
	1½	362.5	364.5	366.5	368.5	370.5	372.5	374.5	376.5

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	25 1/8	25 1/4	25 3/8	25 1/2	25 5/8	25 3/4	25 7/8	26
	3/16	49.94	50.19	50.44	50.69	50.94	51.19	51.44	51.69
6	....	54.03	54.30	54.57	54.85	55.12	55.39	55.66	55.93
	7/32	58.19	58.48	58.77	59.06	59.36	59.65	59.94	60.23
5	....	58.52	58.81	59.11	59.40	59.69	59.99	60.28	60.57
4	....	63.26	63.58	63.90	64.21	64.53	64.85	65.17	65.48
	1/4	66.42	66.75	67.08	67.42	67.75	68.09	68.42	68.75
3	....	68.78	69.13	69.47	69.82	70.17	70.51	70.86	71.20
	9/32	74.63	75.00	75.38	75.75	76.13	76.50	76.88	77.25
2	....	75.35	75.73	76.11	76.48	76.86	77.24	77.62	78.00
1	....	79.54	79.94	80.34	80.74	81.14	81.54	81.94	82.34
	5/16	82.81	83.23	83.65	84.06	84.48	84.90	85.32	85.73
	11/32	90.98	91.44	91.90	92.36	92.82	93.27	93.73	94.19
	3/8	99.13	99.63	100.1	100.6	101.1	101.6	102.1	102.6
	7/16	115.4	115.9	116.5	117.1	117.7	118.3	118.9	119.4
	1/2	131.5	132.2	132.8	133.5	134.2	134.8	135.5	136.2
	9/16	147.6	148.3	149.1	149.8	150.6	151.3	152.1	152.8
	5/8	163.5	164.4	165.2	166.0	166.9	167.7	168.5	169.4
	11/16	179.4	180.4	181.3	182.2	183.1	184.0	184.9	185.9
	3/4	195.2	196.2	197.2	198.3	199.3	200.3	201.3	202.3
	13/16	211.0	212.1	213.1	214.2	215.3	216.4	217.5	218.6
	7/8	226.6	227.8	229.0	230.1	231.3	232.5	233.6	234.8
	15/16	242.2	243.4	244.7	245.9	247.2	248.4	249.7	250.9
	1	257.7	259.0	260.3	261.7	263.0	264.3	265.7	267.0
	1 1/16	273.1	274.5	275.9	277.3	278.7	280.1	281.6	283.0
	1 1/8	288.4	289.9	291.4	292.9	294.4	295.9	297.4	298.9
	1 3/16	303.6	305.2	306.8	308.3	309.9	311.5	313.1	314.7
	1 1/4	318.7	320.4	322.1	323.7	325.4	327.1	328.7	330.4
	1 5/16	333.8	335.5	337.3	339.1	340.8	342.6	344.3	346.1
	1 3/8	348.8	350.6	352.4	354.3	356.1	358.0	359.8	361.6
	1 7/16	363.7	365.6	367.5	369.4	371.3	373.3	375.2	377.1
	1 1/2	378.5	380.5	382.5	384.5	386.5	388.5	390.5	392.5

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	26⅛	26¼	26⅜	26½	26⅝	26¾	26⅞	27
	3/16	51.94	52.19	52.44	52.69	52.94	53.19	53.44	53.69
6	....	56.20	56.47	56.74	57.01	57.28	57.56	57.83	58.10
	7/32	60.52	60.82	61.11	61.40	61.69	61.98	62.28	62.57
5	....	60.87	61.16	61.45	61.75	62.04	62.34	62.63	62.92
4	....	65.80	66.12	66.44	66.75	67.07	67.39	67.71	68.03
	¼	69.09	69.42	69.75	70.09	70.42	70.76	71.09	71.42
3	....	71.55	71.90	72.24	72.59	72.93	73.28	73.62	73.97
	9/32	77.63	78.00	78.38	78.76	79.13	79.51	79.88	80.26
2	....	78.38	78.76	79.14	79.52	79.90	80.28	80.65	81.03
1	....	82.74	83.15	83.55	83.95	84.35	84.75	85.15	85.55
	5/16	86.15	86.57	86.98	87.40	87.82	88.24	88.65	89.07
	11/32	94.65	95.11	95.57	96.03	96.49	96.95	97.40	97.86
	⅜	103.1	103.6	104.1	104.6	105.1	105.6	106.1	106.6
	7/16	120.0	120.6	121.2	121.8	122.4	122.9	123.5	124.1
	½	136.8	137.5	138.2	138.8	139.5	140.2	140.8	141.5
	9/16	153.6	154.3	155.1	155.8	156.6	157.3	158.1	158.8
	⅝	170.2	171.0	171.9	172.7	173.6	174.4	175.2	176.1
	11/16	186.8	187.7	188.6	189.5	190.4	191.4	192.3	193.2
	¾	203.3	204.3	205.3	206.3	207.3	208.3	209.3	210.3
	13/16	219.7	220.7	211.8	222.9	224.0	225.1	226.2	227.2
	⅞	236.0	237.1	238.3	239.5	240.6	241.8	243.0	244.1
	15/16	252.2	253.4	254.7	255.9	257.2	258.5	259.7	261.0
	1	268.3	269.7	271.0	272.3	273.7	275.0	276.3	277.7
	1 1/16	284.4	285.8	287.2	288.7	290.1	291.5	292.9	294.3
	1⅛	300.4	301.9	303.4	304.9	306.4	307.9	309.4	310.9
	1 3/16	316.3	317.9	319.4	321.0	322.6	324.2	325.8	327.4
	1¼	332.1	333.8	335.4	337.1	338.8	340.4	342.1	343.8
	1 5/16	347.8	349.6	351.3	353.1	354.8	356.6	358.3	360.1
	1⅜	363.5	365.3	367.1	369.0	370.8	372.6	374.5	376.3
	1 7/16	379.0	380.9	382.9	384.8	386.7	388.6	390.5	392.5
	1½	394.5	396.5	398.5	400.5	402.5	404.5	406.5	408.5

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	27⅛	27¼	27⅜	27½	27⅝	27¾	27⅞	28
	3/16	53.94	54.19	54.44	54.69	54.94	55.19	55.45	55.70
6	....	58.37	58.64	58.91	59.18	59.45	59.72	59.99	60.27
	7/32	62.86	63.15	63.44	63.74	64.03	64.32	64.61	64.90
5	....	63.22	63.51	63.80	64.10	64.39	64.69	64.98	65.27
4	....	68.34	68.66	68.98	69.30	69.61	69.93	70.25	70.57
	¼	71.76	72.09	72.42	72.76	73.09	73.43	73.76	74.09
3	....	74.32	74.66	75.01	75.35	75.70	76.04	76.39	76.74
	9/32	80.63	81.01	81.38	81.76	82.14	82.51	82.89	83.26
2	....	81.41	81.79	82.17	82.55	82.93	83.31	83.69	84.07
1	....	85.95	86.35	86.75	87.15	87.55	87.95	88.35	88.75
	5/16	89.49	89.91	90.32	90.74	91.16	91.57	91.99	92.41
	11/32	98.32	98.78	99.24	99.70	100.2	100.6	101.1	101.5
	⅜	107.1	107.6	108.1	108.6	109.1	109.6	110.1	110.6
	7/16	124.7	125.3	125.9	126.5	127.0	127.6	128.2	128.8
	½	142.2	142.8	143.5	144.2	144.8	145.5	146.2	146.9
	9/16	159.6	160.3	161.1	161.8	162.6	163.3	164.1	164.8
	⅝	176.9	177.7	178.6	179.4	180.2	181.1	181.9	182.7
	11/16	194.1	195.0	196.0	196.9	197.8	198.7	199.6	200.5
	¾	211.3	212.3	213.3	214.3	215.3	216.3	217.3	218.3
	13/16	228.3	229.4	230.5	231.6	232.7	233.8	234.8	235.9
	⅞	245.3	246.5	247.6	248.8	250.0	251.2	252.3	253.5
	15/16	262.2	263.5	264.7	266.0	267.2	268.5	269.7	271.0
	1	279.0	280.4	281.7	283.0	284.4	285.7	287.0	288.4
	1 1/16	295.7	297.2	298.6	300.0	301.4	302.8	304.3	305.7
	1⅛	312.4	313.9	315.4	316.9	318.4	319.9	321.4	322.9
	1 3/16	329.0	330.5	332.1	333.7	335.3	336.9	338.5	340.1
	1¼	345.4	347.1	348.8	350.4	352.1	353.8	355.4	357.1
	1 5/16	361.8	363.6	365.3	367.1	368.8	370.6	372.3	374.1
	1⅜	378.1	380.0	381.8	383.7	385.5	387.3	389.2	391.0
	1 7/16	394.4	396.3	398.2	400.1	402.0	404.0	405.9	407.8
	1½	410.5	412.5	414.5	416.5	418.5	420.5	422.5	424.5

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	28⅛	28¼	28⅜	28½	28⅝	28¾	28⅞	29
	3/16	55.95	56.20	56.45	56.70	56.95	57.20	57.45	57.70
6	....	60.54	60.81	61.08	61.35	61.62	61.89	62.16	62.43
	7/32	65.20	65.49	65.78	66.07	66.37	66.66	66.95	67.24
5	....	65.57	65.86	66.15	66.45	66.74	67.04	67.33	67.62
4	....	70.89	71.20	71.52	71.84	72.16	72.47	72.79	73.11
	¼	74.43	74.76	75.09	75.43	75.76	76.10	76.43	76.76
3	....	77.08	77.43	77.77	78.12	78.46	78.81	79.16	79.50
	9/32	83.64	84.01	84.39	84.76	85.14	85.51	85.89	86.27
2	....	84.45	84.83	85.20	85.58	85.96	86.34	86.72	87.10
1	....	89.15	89.55	89.95	90.35	90.75	91.16	91.56	91.96
	5/16	92.83	93.24	93.66	94.08	94.49	94.91	95.33	95.75
	11/32	102.0	102.5	102.9	103.4	103.8	104.3	104.7	105.2
	⅜	111.1	111.6	112.1	112.6	113.1	113.6	114.1	114.6
	7/16	129.4	130.0	130.5	131.1	131.7	132.3	132.9	133.5
	½	147.5	148.2	148.9	149.5	150.2	150.9	151.5	152.2
	9/16	165.6	166.3	167.1	167.8	168.6	169.3	170.1	170.8
	⅝	183.6	184.4	185.2	186.1	186.9	187.7	188.6	189.4
	11/16	201.5	202.4	203.3	204.2	205.1	206.1	207.0	207.9
	¾	219.3	220.4	221.3	222.3	223.3	224.3	225.3	226.3
	13/16	237.0	238.1	239.2	240.3	241.3	242.4	243.5	244.6
	⅞	254.7	255.8	257.0	258.2	259.3	260.5	261.7	262.8
	15/16	272.2	273.5	274.7	276.0	277.2	278.5	279.7	281.0
	1	289.7	291.0	292.4	293.7	295.0	296.4	297.7	299.0
	1 1/16	307.1	308.5	309.9	311.4	312.8	314.2	315.6	317.0
	1⅛	324.4	325.9	327.4	328.9	330.4	331.9	333.4	334.9
	1 3/16	341.6	343.2	344.8	346.4	348.0	349.6	351.2	352.7
	1¼	358.8	360.5	362.1	363.8	365.5	367.1	368.8	370.5
	1 5/16	375.8	377.6	379.4	381.1	382.9	384.6	386.4	388.1
	1⅜	392.8	394.7	396.5	398.3	400.2	402.0	403.8	405.7
	1 7/16	409.7	411.6	413.6	415.5	417.4	419.3	421.2	423.2
	1½	426.5	428.5	430.5	432.5	434.5	436.6	438.6	440.6

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	31⅛	31¼	31⅜	31½	31⅝	31¾	31⅞	32
	3/16	61.95	62.20	62.45	62.70	62.95	63.20	63.46	63.71
6	....	67.04	67.31	67.58	67.85	68.13	68.40	68.67	68.94
	7/32	72.21	72.50	72.79	73.08	73.37	73.67	73.96	74.25
5	....	72.62	72.91	73.20	73.50	73.79	74.08	74.38	74.67
4	....	78.51	78.83	79.15	79.46	79.78	80.10	80.42	80.74
	¼	82.44	82.77	83.10	83.44	83.77	84.11	84.44	84.77
3	....	85.38	85.73	86.07	86.42	86.76	87.11	87.45	87.80
	9/32	92.65	93.02	93.40	93.77	94.15	94.53	94.90	95.28
2	....	93.55	93.92	94.30	94.68	95.06	95.44	95.82	96.20
1	....	98.76	99.17	99.57	99.97	100.4	100.8	101.2	101.6
	5/16	102.8	103.3	103.7	104.1	104.5	104.9	105.3	105.8
	11/32	113.0	113.5	113.9	114.4	114.8	115.3	115.8	116.2
	⅜	123.2	123.7	124.2	124.7	125.2	125.7	126.2	126.7
	7/16	143.4	144.0	144.6	145.1	145.7	146.3	146.9	147.5
	½	163.5	164.2	164.9	165.5	166.2	166.9	167.5	168.2
	9/16	183.6	184.4	185.1	185.9	186.6	187.4	188.1	188.9
	⅝	203.6	204.4	205.3	206.1	206.9	207.8	208.6	209.4
	11/16	223.5	224.4	225.3	226.2	227.2	228.1	229.0	229.9
	¾	243.3	244.3	245.3	246.3	247.3	248.3	249.3	250.3
	13/16	263.0	264.1	265.2	266.3	267.4	268.5	269.5	270.6
	⅞	282.7	283.9	285.0	286.2	287.4	288.5	289.7	290.9
	15/16	302.2	303.5	304.8	306.0	307.3	308.5	309.8	311.0
	1	321.7	323.1	324.4	325.7	327.1	328.4	329.7	331.1
	1 1/16	341.1	342.6	344.0	345.4	346.8	348.2	349.6	351.1
	1⅛	360.5	362.0	363.5	365.0	366.5	368.0	369.5	371.0
	1 3/16	379.7	381.3	382.9	384.4	386.0	387.6	389.2	390.8
	1¼	398.8	400.5	402.2	403.8	405.5	407.2	408.9	410.5
	1 5/16	417.9	419.7	421.4	423.2	424.9	426.7	428.4	430.2
	1⅜	436.9	438.7	440.6	442.4	444.2	446.1	447.9	449.7
	1 7/16	455.8	457.7	459.6	461.5	463.5	465.4	467.3	469.2
	1½	474.6	476.6	478.6	480.6	482.6	484.6	486.6	488.6

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	32⅛	32¼	32⅜	32½	32⅝	32¾	32⅞	33
	3/16	63.96	64.21	64.46	64.71	64.96	65.21	65.46	65.71
6	....	69.21	69.48	69.75	70.02	70.29	70.56	70.84	71.11
	7/32	74.54	74.83	75.13	75.42	75.71	76.00	76.29	76.59
5	....	74.97	75.26	75.55	75.85	76.14	76.43	76.73	77.02
4	....	81.05	81.37	81.69	82.01	82.32	82.64	82.96	83.28
	¼	85.11	85.44	85.78	86.11	86.44	86.78	87.11	87.44
3	....	88.15	88.49	88.84	89.18	89.53	89.88	90.22	90.57
	9/32	95.65	96.03	96.40	96.78	97.15	97.53	97.90	98.28
2	....	96.58	96.96	97.34	97.72	98.10	98.47	98.85	99.23
1	....	102.0	102.4	102.8	103.2	103.6	104.0	104.4	104.8
	5/16	106.2	106.6	107.0	107.4	107.8	108.3	108.7	109.1
	11/32	116.7	117.1	117.6	118.1	118.5	119.0	119.4	119.9
	⅜	127.2	127.7	128.2	128.7	129.2	129.7	130.2	130.7
	7/16	148.1	148.6	149.2	149.8	150.4	151.0	151.6	152.2
	½	168.9	169.5	170.2	170.9	171.6	172.2	172.9	173.6
	9/16	189.6	190.4	191.1	191.9	192.6	193.4	194.1	194.9
	⅝	210.3	211.1	211.9	212.8	213.6	214.4	215.3	216.1
	11/16	230.8	231.8	232.7	233.6	234.5	235.4	236.3	237.3
	¾	251.3	252.3	253.3	254.3	255.3	256.3	257.3	258.3
	13/16	271.7	272.8	273.9	275.0	276.1	277.1	278.2	279.3
	⅞	292.0	293.2	294.4	295.5	296.7	297.9	299.0	300.2
	15/16	312.3	313.5	314.8	316.0	317.3	318.5	319.8	321.0
	1	332.4	333.8	335.1	336.4	337.8	339.1	340.4	341.8
	1 1/16	352.5	353.9	355.3	356.7	358.2	359.6	361.0	362.4
	1⅛	372.5	374.0	375.5	377.0	378.5	380.0	381.5	383.0
	1 3/16	392.4	394.0	395.5	397.1	398.7	400.3	401.9	403.5
	1¼	412.2	413.9	415.5	417.2	418.9	420.5	422.2	423.9
	1 5/16	431.9	433.7	435.4	437.2	438.9	440.7	442.4	444.2
	1⅜	451.6	453.4	455.2	457.1	458.9	460.7	462.6	464.4
	1 7/16	471.1	473.1	475.0	476.9	478.8	480.7	482.7	484.6
	1½	490.6	492.6	494.6	496.6	498.6	500.6	502.6	504.6

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	31⅛	31¼	31⅜	31½	31⅝	31¾	31⅞	32
	3/16	61.95	62.20	62.45	62.70	62.95	63.20	63.46	63.71
6	....	67.04	67.31	67.58	67.85	68.13	68.40	68.67	68.94
	7/32	72.21	72.50	72.79	73.08	73.37	73.67	73.96	74.25
5	....	72.62	72.91	73.20	73.50	73.79	74.08	74.38	74.67
4	....	78.51	78.83	79.15	79.46	79.78	80.10	80.42	80.74
	¼	82.44	82.77	83.10	83.44	83.77	84.11	84.44	84.77
3	....	85.38	85.73	86.07	86.42	86.76	87.11	87.45	87.80
	9/32	92.65	93.02	93.40	93.77	94.15	94.53	94.90	95.28
2	....	93.55	93.92	94.30	94.68	95.06	95.44	95.82	96.20
1	....	98.76	99.17	99.57	99.97	100.4	100.8	101.2	101.6
	5/16	102.8	103.3	103.7	104.1	104.5	104.9	105.3	105.8
	11/32	113.0	113.5	113.9	114.4	114.8	115.3	115.8	116.2
	⅜	123.2	123.7	124.2	124.7	125.2	125.7	126.2	126.7
	7/16	143.4	144.0	144.6	145.1	145.7	146.3	146.9	147.5
	½	163.5	164.2	164.9	165.5	166.2	166.9	167.5	168.2
	9/16	183.6	184.4	185.1	185.9	186.6	187.4	188.1	188.9
	⅝	203.6	204.4	205.3	206.1	206.9	207.8	208.6	209.4
	11/16	223.5	224.4	225.3	226.2	227.2	228.1	229.0	229.9
	¾	243.3	244.3	245.3	246.3	247.3	248.3	249.3	250.3
	13/16	263.0	264.1	265.2	266.3	267.4	268.5	269.5	270.6
	⅞	282.7	283.9	285.0	286.2	287.4	288.5	289.7	290.9
	15/16	302.2	303.5	304.8	306.0	307.3	308.5	309.8	311.0
	1	321.7	323.1	324.4	325.7	327.1	328.4	329.7	331.1
	1 1/16	341.1	342.6	344.0	345.4	346.8	348.2	349.6	351.1
	1⅛	360.5	362.0	363.5	365.0	366.5	368.0	369.5	371.0
	1 3/16	379.7	381.3	382.9	384.4	386.0	387.6	389.2	390.8
	1¼	398.8	400.5	402.2	403.8	405.5	407.2	408.9	410.5
	1 5/16	417.9	419.7	421.4	423.2	424.9	426.7	428.4	430.2
	1⅜	436.9	438.7	440.6	442.4	444.2	446.1	447.9	449.7
	1 7/16	455.8	457.7	459.6	461.5	463.5	465.4	467.3	469.2
	1½	474.6	476.6	478.6	480.6	482.6	484.6	486.6	488.6

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	32 1/8	32 1/4	32 3/8	32 1/2	32 5/8	32 3/4	32 7/8	33
	3/16	63.96	64.21	64.46	64.71	64.96	65.21	65.46	65.71
6	....	69.21	69.48	69.75	70.02	70.29	70.56	70.84	71.11
	7/32	74.54	74.83	75.13	75.42	75.71	76.00	76.29	76.59
5	....	74.97	75.26	75.55	75.85	76.14	76.43	76.73	77.02
4	....	81.05	81.37	81.69	82.01	82.32	82.64	82.96	83.28
	1/4	85.11	85.44	85.78	86.11	86.44	86.78	87.11	87.44
3	....	88.15	88.49	88.84	89.18	89.53	89.88	90.22	90.57
	9/32	95.65	96.03	96.40	96.78	97.15	97.53	97.90	98.28
2	....	96.58	96.96	97.34	97.72	98.10	98.47	98.85	99.23
1	....	102.0	102.4	102.8	103.2	103.6	104.0	104.4	104.8
	5/16	106.2	106.6	107.0	107.4	107.8	108.3	108.7	109.1
	11/32	116.7	117.1	117.6	118.1	118.5	119.0	119.4	119.9
	3/8	127.2	127.7	128.2	128.7	129.2	129.7	130.2	130.7
	7/16	148.1	148.6	149.2	149.8	150.4	151.0	151.6	152.2
	1/2	168.9	169.5	170.2	170.9	171.6	172.2	172.9	173.6
	9/16	189.6	190.4	191.1	191.9	192.6	193.4	194.1	194.9
	5/8	210.3	211.1	211.9	212.8	213.6	214.4	215.3	216.1
	11/16	230.8	231.8	232.7	233.6	234.5	235.4	236.3	237.3
	3/4	251.3	252.3	253.3	254.3	255.3	256.3	257.3	258.3
	13/16	271.7	272.8	273.9	275.0	276.1	277.1	278.2	279.3
	7/8	292.0	293.2	294.4	295.5	296.7	297.9	299.0	300.2
	15/16	312.3	313.5	314.8	316.0	317.3	318.5	319.8	321.0
	1	332.4	333.8	335.1	336.4	337.8	339.1	340.4	341.8
	1 1/16	352.5	353.9	355.3	356.7	358.2	359.6	361.0	362.4
	1 1/8	372.5	374.0	375.5	377.0	378.5	380.0	381.5	383.0
	1 3/16	392.4	394.0	395.5	397.1	398.7	400.3	401.9	403.5
	1 1/4	412.2	413.9	415.5	417.2	418.9	420.5	422.2	423.9
	1 5/16	431.9	433.7	435.4	437.2	438.9	440.7	442.4	444.2
	1 3/8	451.6	453.4	455.2	457.1	458.9	460.7	462.6	464.4
	1 7/16	471.1	473.1	475.0	476.9	478.8	480.7	482.7	484.6
	1 1/2	490.6	492.6	494.6	496.6	498.6	500.6	502.6	504.6

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	33⅛	33¼	33⅜	33½	33⅝	33¾	33⅞	34
	3/16	65.96	66.21	66.46	66.71	66.96	67.21	67.46	67.71
6	....	71.38	71.65	71.92	72.19	72.46	72.73	73.00	73.27
	7/32	76.88	77.17	77.46	77.75	78.05	78.34	78.63	78.92
5	....	77.31	77.61	77.90	78.20	78.49	78.78	79.08	79.37
4	....	83.59	83.91	84.23	84.55	84.87	85.18	85.50	85.82
	¼	87.78	88.11	88.45	88.78	89.11	89.45	89.78	90.11
3	....	90.91	91.26	91.60	91.95	92.30	92.64	92.99	93.33
	9/32	98.66	99.03	99.41	99.78	100.2	100.5	100.9	101.3
2	....	99.61	99.99	100.4	100.7	101.1	101.5	101.9	102.3
1	....	105.2	105.6	106.0	106.4	106.8	107.2	107.6	108.0
	5/16	109.5	109.9	110.3	110.8	111.2	111.6	112.0	112.4
	11/32	120.3	120.8	121.3	121.7	122.2	122.6	123.1	123.6
	⅜	131.2	131.7	132.2	132.7	133.2	133.7	134.2	134.7
	7/16	152.7	153.3	153.9	154.5	155.1	155.7	156.2	156.8
	½	174.2	174.9	175.6	176.2	176.9	177.6	178.2	178.9
	9/16	195.6	196.4	197.1	197.9	198.6	199.4	200.1	200.9
	⅝	216.9	217.8	218.6	219.4	220.3	221.1	221.9	222.8
	11/16	238.2	239.1	240.0	240.9	241.8	242.8	243.7	244.6
	¾	259.3	260.3	261.3	262.3	263.3	264.3	265.3	266.3
	13/16	280.4	281.5	282.6	283.6	284.7	285.8	286.9	288.0
	⅞	301.4	302.5	303.7	304.9	306.1	307.2	308.4	309.6
	15/16	322.3	323.5	324.8	326.0	327.3	328.5	329.8	331.0
	1	343.1	344.4	345.8	347.1	348.4	349.8	351.1	352.4
	1 1/16	363.8	365.3	366.7	368.1	369.5	370.9	372.3	373.8
	1⅛	384.5	386.0	387.5	389.0	390.5	392.0	393.5	395.0
	1 3/16	405.1	406.6	408.2	409.8	411.4	413.0	414.6	416.2
	1¼	425.5	427.2	428.9	430.5	432.2	433.9	435.6	437.2
	1 5/16	445.9	447.7	449.4	451.2	452.9	454.7	456.5	458.2
	1⅜	466.3	468.1	469.9	471.8	473.6	475.4	477.3	479.1
	1 7/16	486.5	488.4	490.3	492.2	494.2	496.1	498.0	499.9
	1½	506.6	508.6	510.6	512.6	514.7	516.7	518.7	520.7

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Continued)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	34⅛	34¼	34⅜	34½	34⅝	34¾	34⅞	35
	3/16	67.96	68.21	68.46	68.71	68.96	69.21	69.46	69.71
6	....	73.55	73.82	74.09	74.36	74.63	74.90	75.17	75.44
	7/32	79.21	79.51	79.80	80.09	80.38	80.67	80.97	81.26
5	....	79.66	79.96	80.25	80.55	80.84	81.13	81.43	81.72
4	....	86.14	86.45	86.77	87.09	87.41	87.73	88.04	88.36
	¼	90.45	90.78	91.12	91.45	91.78	92.12	92.45	92.78
3	....	93.68	94.02	94.37	94.72	95.06	95.41	95.75	96.10
	9/32	101.7	102.0	102.4	102.8	103.2	103.5	103.9	104.3
2	....	102.6	103.0	103.4	103.8	104.2	104.5	104.9	105.3
1	....	108.4	108.8	109.2	109.6	110.0	110.4	110.8	111.2
	5/16	112.9	113.3	113.7	114.1	114.5	114.9	115.4	115.8
	11/32	124.0	124.5	124.9	125.4	125.9	126.3	126.8	127.2
	⅜	135.2	135.7	136.2	136.7	137.2	137.7	138.2	138.7
	7/16	157.4	158.0	158.6	159.2	159.7	160.3	160.9	161.5
	½	179.6	180.2	180.9	181.6	182.2	182.9	183.6	184.2
	9/16	201.6	202.4	203.1	203.9	204.6	205.4	206.1	206.9
	⅝	223.6	224.5	225.3	226.1	227.0	227.8	228.6	229.5
	11/16	245.5	246.4	247.4	248.3	249.2	250.1	251.0	251.9
	¾	267.3	268.3	269.3	270.3	271.3	272.3	273.3	274.3
	13/16	289.1	290.2	291.2	292.3	293.4	294.5	295.6	296.7
	⅞	310.7	311.9	313.1	314.2	315.4	316.6	317.7	318.9
	15/16	332.3	333.5	334.8	336.0	337.3	338.6	339.8	341.1
	1	353.8	355.1	356.5	357.8	359.1	360.5	361.8	363.1
	1 1/16	375.2	376.6	378.0	379.4	380.9	382.3	383.7	385.1
	1⅛	396.5	398.0	399.5	401.0	402.5	404.0	405.5	407.0
	1 3/16	417.7	419.3	420.9	422.5	424.1	425.7	427.2	428.8
	1¼	438.9	440.6	442.2	443.9	445.6	447.2	448.9	450.6
	1 5/16	460.0	461.7	463.5	465.2	467.0	468.7	470.5	472.2
	1⅜	480.9	482.8	484.6	486.4	488.3	490.1	492.0	493.8
	1 7/16	501.8	503.8	505.7	507.6	509.5	511.4	513.4	515.3
	1½	522.7	524.7	526.7	528.7	530.7	532.7	534.7	536.7

Table II. — Weight in Pounds per Lineal Foot for Steel Pipe and Tubing (Concluded)

Weight 1 cubic inch Steel = .2833 pound

Wall thickness		Outside diameter in inches							
B.W.G.	Inches	35⅛	35¼	35⅜	35½	35⅝	35¾	35⅞	36
	3/16	69.96	70.21	70.46	70.71	70.96	71.21	71.47	71.72
6	....	75.71	75.98	76.26	76.53	76.80	77.07	77.34	77.61
	7/32	81.55	81.84	82.13	82.43	82.72	83.01	83.30	83.60
5	....	82.01	82.31	82.60	82.90	83.19	83.48	83.78	84.07
4	....	88.68	89.00	89.31	89.63	89.95	90.27	90.58	90.90
	¼	93.12	93.45	93.79	94.12	94.45	94.79	95.12	95.45
3	....	96.45	96.79	97.14	97.48	97.83	98.17	98.52	98.87
	9/32	104.7	105.0	105.4	105.8	106.2	106.5	106.9	107.3
2	....	105.7	106.1	106.4	106.8	107.2	107.6	108.0	108.3
1	....	111.6	112.0	112.4	112.8	113.2	113.6	114.0	114.4
	5/16	116.2	116.6	117.0	117.4	117.9	118.3	118.7	119.1
	11/32	127.7	128.2	128.6	129.1	129.5	130.0	130.4	130.9
	⅜	139.2	139.7	140.2	140.7	141.2	141.7	142.2	142.7
	7/16	162.1	162.7	163.2	163.8	164.4	165.0	165.6	166.2
	½	184.9	185.6	186.2	186.9	187.6	188.2	188.9	189.6
	9/16	207.6	208.4	209.1	209.9	210.6	211.4	212.1	212.9
	⅝	230.3	231.1	232.0	232.8	233.6	234.5	235.3	236.1
	11/16	252.9	253.8	254.7	255.6	256.5	257.5	258.4	259.3
	¾	275.3	276.3	277.4	278.4	279.4	280.4	281.4	282.4
	13/16	297.8	298.8	299.9	301.0	302.1	303.2	304.3	305.3
	⅞	320.1	321.2	322.4	323.6	324.7	325.9	327.1	328.2
	15/16	342.3	343.6	344.8	346.1	347.3	348.6	349.8	351.1
	1	364.5	365.8	367.1	368.5	369.8	371.1	372.5	373.8
	1 1/16	386.5	387.9	389.4	390.8	392.2	393.6	395.0	396.5
	1⅛	408.5	410.0	411.5	413.0	414.5	416.0	417.5	419.0
	1 3/16	430.4	432.0	433.6	435.2	436.8	438.3	439.9	441.5
	1¼	452.2	453.9	455.6	457.2	458.9	460.6	462.3	463.9
	1 5/16	474.0	475.7	477.5	479.2	481.0	482.7	484.5	486.2
	1⅜	495.6	497.5	499.3	501.1	503.0	504.8	506.6	508.5
	1 7/16	517.2	519.1	521.0	523.0	524.9	526.8	528.7	530.6
	1½	538.7	540.7	542.7	544.7	546.7	548.7	550.7	552.7

TABLE OF THE PROPERTIES OF TUBES AND ROUND BARS

Plan of Table. This table was planned with a view of stating the properties of tubes and pipe in the best form for application to practice. The scheme is based upon the fact that a hollow cylinder, or tube, may always be considered as the difference of two solid cylinders. Thus the hollow cylinder or tube, Fig. 134, may be considered as resulting from the removal of the smaller cylinder, Fig. 133, from the center of the larger cylinder, Fig. 132.

Fig. 132

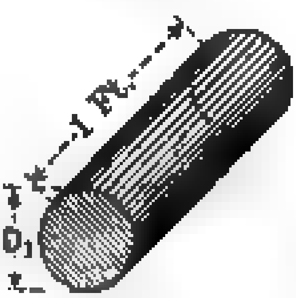


Fig. 133

Fig. 134

In order to be able to apply this table to the solution of problems in tubular mechanics, it will only be necessary, in addition to having the above fundamental relation clearly in mind, to remember that the table states the properties of a series of solid round bars, each one foot long, whose diameters advance by .01 inch to 16 inches, and thereafter by ⅛ inch.

Calculation of Table. The table was calculated on an eight-slot Burkhardt machine, making use of the following data:

D = diameter of a round bar in inches.

$C = \pi D = 3.1415927\, D$ = circumference of a cross-section in inches.

$A = \frac{\pi}{4} D^2 = 0.78539816\, D^2$ = area of cross-section in square inches.

$S = \frac{C}{12} = \frac{\pi}{12} D = 0.26179939\, D$ = cylindrical surface in square feet per foot length.

$V = 12\, A = 3\, \pi D^2 = 9.4247780\, D^2$ = volume in cubic inches per foot length.

$W = 0.2833\, V = 3.3996\, A = 2.6700396\, D^2$ = weight of a round steel bar in pounds per foot length.

$R^2 = \frac{D^2}{16} = 0.0625\, D^2$ = radius of gyration of cross-section, squared.

$I = \frac{\pi}{64} D^4 = 0.049087385\, D^4 = \frac{\pi}{4} D^2 \times \frac{D^2}{16} = AR^2$ = moment of inertia of cross-section.

$y = \frac{1}{2} D$ = distance of farthest fiber from the axis of a round bar in inches.

Weight of one cubic inch of steel = 0.2833 pound.

The last value stated in each of the above formulæ is the one actually used in making the calculations.

The machine calculations, except for the moment of inertia, I, were all carried out to the respective degrees of accuracy indicated by the constants of the above formulæ. Each result was then contracted to a lesser number of significant figures for the reason explained below. The moment of inertia, I, was obtained by multiplying the area of cross-section, A, by the corresponding radius of gyration squared, R^2, both being taken to six significant figures.

Precision of Tabular Statement. While entering the calculated values in this table, care was taken to have the precision of statement just sufficient to meet the demands of practice. The number of significant figures given in the different columns corresponding to any tabular diameter is based upon the assumption that diameters are measured to the nearest one-thousandth of an inch, thus involving a possible error of 0.0005 inch. This error in the diameter of a round bar will give rise to corresponding errors in its volume, weight, moment of inertia, and other properties. An investigation has shown these resulting errors to be as follows: For C, 0.00157 inch; for A, 0.000785 D; for S, 0.000131 square inch; for V, 0.00942 D; for W, 0.00267 D; for R^2, 0.0000625 D; for I, 0.000098 D^3; and for y, 0.00025 inch.

Checking of Tabular Values. Each individual entry of this table has been calculated twice, and wherever a difference was found a third independent calculation was made to decide which of the two values in question was in error. The second calculation was made after the table had been traced, and all errors found were corrected directly on the tracings. A set of blue-prints was then made, and this was finally checked by the well-known method of differences.

APPLICATION OF TABLE TO ROUND BARS

For the properties of round bars use the different tabular values direct. Thus for a round steel bar 6.35 inches in diameter, turn to the table, page 436, headed $\frac{6.00}{6.50}$ inches, and opposite 6.35, in column D, take the required properties from the table as follows: For circumference of cross-section, 19.949 inches; for area of cross-section, 31.669 square inches; for cylindrical surface, 1.6624 square feet per foot length; for volume, 380.03 cubic inches per foot length; for weight of steel bar, 107.66 pounds per foot length; for moment of inertia of cross-section, 79.81, from which the *polar moment of inertia*, being equal to twice the moment of inertia, is 79.81 × 2, or 159.62; for distance from axis of the bar to the most remote fiber, 3.175 inches; and for the square of the radius of gyration of cross-section, 2.5202.

The table is applicable to diameters when stated in inches and hundredths to 16 inches and thereafter when stated in inches and eighths.

When diameters are stated to thousandths of an inch, interpolate in the usual way as follows: For example, to find the weight in pounds

per lineal foot, of a round steel bar 6.356 inches diameter, add to the tabular weight corresponding to 6.35, six-tenths of the difference of weights corresponding to diameters of 6.36 and 6.35; thus, difference of these weights is $108.00 - 107.66 = 0.34$; and six-tenths of this difference is $0.34 \times 0.6 = 0.204$; which added to the weight corresponding to 6.35 diameter gives $107.66 + 0.204 = 107.86$ pounds per lineal foot as the weight of a bar 6.356 inches in diameter. Similarly all the other properties may be obtained; thus, moment of inertia, $I, = 79.81 + 0.6\,(80.32 - 79.81) = 79.81 + 0.31 = 80.12$.

When diameters are stated to sixteenths, thirty-seconds, or sixty-fourths, above 16 inches interpolate similarly. Thus the weight of a round bar 18⁵⁄₃₂ inches in diameter, since this diameter lies between 18⅛ and 18¼, will be (weight for 18⅛) + $\left(\frac{5/32 - 1/8}{1/4 - 1/8}\right)$ (weight for 18¼ − weight for 18⅛) or $877.15 + \frac{1}{4}$ of $(889.29 - 877.15) = 877.15 + 3.04 = 880.19$ pounds per lineal foot.

To Find Diameter of Bar Corresponding to a Given Property. This is accomplished by taking the diameter opposite the tabular property nearest to that stated. For example, to find what diameter of round bar will correspond to a moment of inertia of 46, look down column I of the table until 45.91 is reached, which is the nearest tabular value, and then read opposite, in column D, 5.53 inches as the diameter required. Similarly a round bar of 15 square inches cross-sectional area will have a diameter of 4.37 inches, as read opposite 14.999 in column A.

APPLICATION OF TABLE TO TUBES AND PIPE

Let it be required to find the properties of a tube having outside and inside diameters of 7.62 and 7.02 inches respectively.

It will be observed that according to the plan of this table (see page 419) the different properties of a tube may be grouped as follows:

(1) *The circumference, surface, fluid capacity, and distance of the farthest fiber from the axis are to be used direct as taken from the table.* For the above example these will be as follows. From the table, column C, the outside circumference, opposite 7.62, is 23.939 inches; and the inside circumference, opposite 7.02, is 22.054 inches; from column S, similarly the outside and inside surfaces are found to be respectively 1.9949 and 1.8378 square feet per foot length of tube; from column V, the fluid capacity will be found opposite 7.02, the inside diameter, and is 464.46 cubic inches per foot length; while from column y, the distance of the farthest fiber from the axis of the tube will be found opposite the outside diameter, 7.62, and is 3.810 inches.

Fig. 135

(2) *The area of cross-section, volume of wall, weight, and moment of inertia for a tube are obtained by taking the difference of the respective*

tabular values corresponding to the outside and inside diameters of the tube. For the above example they will be as follows: From column *A*, opposite 7.62, the outside diameter of the tube, read 45.604, and opposite 7.02, the inside diameter, read 38.705. The difference of these, or $45.604 - 38.705 = 6.899$ square inches, is the required sectional area of tube wall. Similarly from column *V*, the volume of the tube wall is $547.24 - 464.46 = 82.78$ cubic inches; from column *W*, the weight of tube is $155.03 - 131.58 = 23.45$ pounds per foot length; and from column *I*, the moment of inertia of cross-section is $165.50 - 119.21 = 46.29$. *Note that the polar moment of inertia, being equal to twice the moment of inertia, will be* 46.29×2, or 92.58.

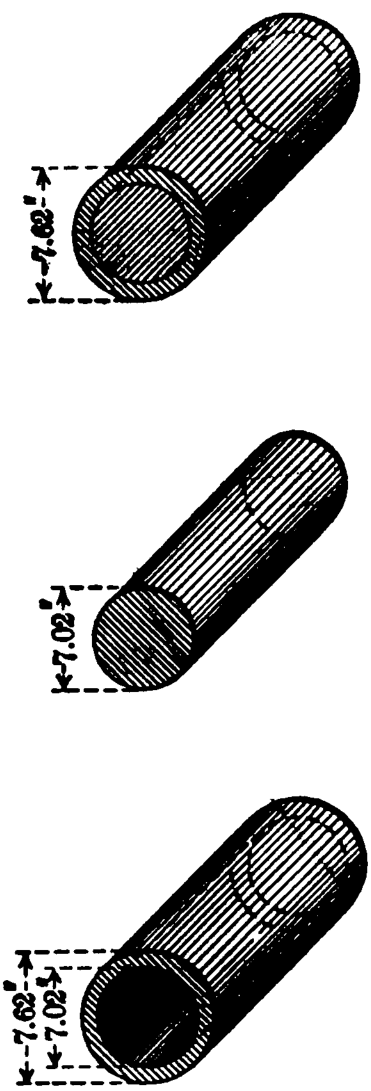


Fig. 136

(3) *The radius of gyration, squared, for a tube is obtained by taking the sum of the radii of gyration, squared, corresponding to the outside and inside diameters of the tube.* For the above example, from column R^2, opposite 7.62, the outside diameter of the tube, read 3.6290, and opposite 7.02, the inside diameter, read 3.0800. The ***sum*** of these, or $3.6290 + 3.0800 = 6.7090$ is the square of the required radius of gyration. Note that the sum is to be taken here, and not the difference, as in the preceding case.

To Find the Diameters of Tubes Corresponding to Given Properties. This table may be used for the solution of a great variety of problems of this character, of which the following is a representative example:

When one diameter and either the sectional area, weight, or moment of inertia are given, to find the other diameter and thickness of wall.

Remembering that a tube may be considered as the difference between two solid cylinders, it is evident that the weight, for example, of the smaller cylinder will equal the weight of the larger cylinder minus the weight of the tube, and that the required inside diameter of the tube is the same as the diameter of the smaller cylinder, we proceed as follows:

For a tube that shall weigh 16 pounds per foot, for example, when the outside diameter is six inches, we find from the table, opposite 6.00 in column *D*, 96.12 in column *W*, which is the weight of a six-inch round steel bar in pounds per foot length. Subtracting 16.00 pounds, the given weight of tube per foot, we get $96.12 - 16.00 = 80.12$ as the weight per foot of a round steel bar whose diameter must be the same as the required inside diameter of the tube. From column *W*, the nearest tabular weight is found to be 80.18, opposite which we read, in column *D*, 5.48 inches as the inside diameter required. The thickness of wall will then be one-half the difference of the diameters, or $\frac{1}{2}(6.00 - 5.48) = 0.26$ inch.

When the inside diameter is given and the outside diameter required, we must add the weight of the tube to that of the smaller cylinder; otherwise the two solutions are identical.

In a similar manner to the above we can find the *thickness of wall corresponding to a given sectional area or moment of inertia.* For example, to find the inside diameter of a six-inch tube that shall have a moment of inertia of 32, proceed as follows: From column I, opposite 6.00, we read 63.62, which is the moment of inertia of a solid bar six inches in diameter. Subtracting 32, we get $63.62 - 32 = 31.62$ as the moment of inertia of a solid round bar that would just fill up the interior of the required tube. The nearest tabular value in column I we find to be 31.67, opposite which we read 5.04 inches as the required inside diameter of the tube. The thickness of wall will then be $\frac{1}{2}(6.00 - 5.04) = 0.48$ inch.

Weight Factors for Different Materials

In the following formulæ V is the tabular volume in cubic inches, and W the tabular weight for wrought steel.

Weight of wrought iron...........	$= V \times .278$	$= W -$	2 per cent.
Weight of cast iron...............	$= V \times .260$	$= W -$	8 per cent.
Weight of wrought copper.........	$= V \times .320$	$= W +$	13 per cent.
Weight of wrought brass..........	$= V \times .303$	$= W +$	7 per cent.
Weight of wrought nickel..........	$= V \times .313$	$= W +$	10½ per cent.
Weight of lead....................	$= V \times .411$	$= W +$	45 per cent.
Weight of tin.....................	$= V \times .267$	$= W -$	6 per cent.
Weight of cast aluminum	$= V \times .092$	$= W -$	67½ per cent.
Weight of wrought aluminum......	$= V \times .097$	$= W -$	66 per cent.

These multipliers are the weights of a cubic inch of the respective materials. They have been compiled from various sources and may be accepted as representing good average values for use in case more exact values are not at hand. The percentage column was calculated from the column of multipliers here given, and is expressed to the nearest one-half per cent only.

The weight of a cubic inch of soft wrought steel used in the calculation of the tabular weights, column W, was taken as 0.2833 pound, the value that is commonly accepted for rolled steel. More exact average values are 0.2831 for welded steel tubes, and 0.2834 for seamless steel tubes. It should be noted (1) that the adopted tabular value is the average of these two, and (2) that the three values are in substantial agreement, so far as commercial weighing is concerned, the differences being 1½ and ¾ pounds per ton respectively for welded and seamless tubes.

Capacity Factors for Tubes

The different capacities of a tube or pipe per lineal foot may be obtained by applying the following formulæ, where V is the tabular volume in cubic inches:

Capacity in cubic feet.................	$= V \div 1728$	$= V \times .0005787$
Capacity in gallons (U. S.).............	$= V \div 231$	$= V \times .004329$
Capacity in cubic centimeters........................		$= V \times 16.387$
Capacity in liters..............................		$= V \times .016387$
Capacity in pounds pure water at 39.2° F............		$= V \times .03613$
Capacity in pounds pure water at 62° F.............		$= V \times .03609$
Capacity in pounds carbonic acid for density of .62...		$= V \times .02240$

Properties of Tubes and Round Bars

.00 inch
.50 inch

For Tubes use differences for A, W, I and V (for volume of wall only), sum for R^2, and direct tabular values for C, S, y and V (for capacity). For Round Bars use all tabular values direct.

Diam. in inches D	Circumference in inches C	Area cross section sq. in. A	Per foot length: Surface sq. ft. S	Per foot length: Volume cu. in. V	Per foot length: Weight, lbs. steel W	Moment of inertia I	Distance from axis to farthest fiber y	Radius of gyration squared R^2
.00	.000	.000000	.0000	.00000	.00000	.0000000000	.000	.0000000
.01	.031	.000079	.0026	.00094	.00027	.0000000005	.005	.0000063
.02	.063	.00031	.0052	.0038	.00107	.0000000079	.010	.000025
.03	.094	.00071	.0079	.0085	.00240	.000000040	.015	.000056
.04	.126	.00126	.0105	.0151	.0043	.000000126	.020	.000100
.05	.157	.00196	.0131	.0236	.0067	.00000031	.025	.000156
.06	.188	.00283	.0157	.0339	.0096	.00000064	.030	.000225
.07	.220	.00385	.0183	.0462	.0131	.00000118	.035	.000306
.08	.251	.00503	.0209	.0603	.0171	.00000201	.040	.000400
.09	.283	.00636	.0236	.0763	.0216	.00000322	.045	.000506
.10	.314	.00785	.0262	.0942	.0267	.00000491	.050	.000625
.11	.346	.00950	.0288	.114	.0323	.0000072	.055	.000756
.12	.377	.01131	.0314	.136	.0384	.0000102	.060	.000900
.13	.408	.0133	.0340	.159	.0451	.0000140	.065	.001056
.14	.440	.0154	.0367	.185	.0523	.0000189	.070	.001225
.15	.471	.0177	.0393	.212	.0601	.0000248	.075	.001406
.16	.503	.0201	.0419	.241	.0684	.0000322	.080	.00160
.17	.534	.0227	.0445	.272	.0772	.0000410	.085	.00181
.18	.565	.0254	.0471	.305	.0865	.0000515	.090	.00203
.19	.597	.0284	.0497	.340	.0964	.0000640	.095	.00226
.20	.628	.0314	.0524	.377	.1068	.0000785	.100	.00250
.21	.660	.0346	.0550	.416	.1177	.0000955	.105	.00276
.22	.691	.0380	.0576	.456	.1292	.000115	.110	.00303
.23	.723	.0415	.0602	.499	.1412	.000137	.115	.00331
.24	.754	.0452	.0628	.543	.1538	.000163	.120	.00360
.25	.785	.0491	.0654	.589	.1669	.000192	.125	.00391
.26	.817	.0531	.0681	.637	.1805	.000224	.130	.00423
.27	.848	.0573	.0707	.687	.1946	.000261	.135	.00456
.28	.880	.0616	.0733	.739	.2093	.000302	.140	.00490
.29	.911	.0661	.0759	.793	.2246	.000347	.145	.00526
.30	.942	.0707	.0785	.848	.2403	.000398	.150	.00563
.31	.974	.0755	.0812	.906	.2566	.000453	.155	.00601
.32	1.005	.0804	.0838	.965	.2734	.000515	.160	.00640
.33	1.037	.0855	.0864	1.026	.2908	.000582	.165	.00681
.34	1.068	.0908	.0890	1.090	.3087	.000656	.170	.00723
.35	1.100	.0962	.0916	1.155	.3271	.000737	.175	.00766
.36	1.131	.1018	.0942	1.221	.3460	.000824	.180	.00810
.37	1.162	.1075	.0969	1.290	.3655	.000920	.185	.00856
.38	1.194	.1134	.0995	1.361	.386	.001024	.190	.00903
.39	1.225	.1195	.1021	1.434	.406	.001136	.195	.00951
.40	1.257	.1257	.1047	1.508	.427	.001257	.200	.01000
.41	1.288	.1320	.1073	1.584	.449	.001387	.205	.01051
.42	1.319	.1385	.1100	1.663	.471	.001527	.210	.01103
.43	1.351	.1452	.1126	1.743	.494	.001678	.215	.01156
.44	1.382	.1521	.1152	1.825	.517	.001840	.220	.01210
.45	1.414	.1590	.1178	1.909	.541	.002013	.225	.01266
.46	1.445	.1662	.1204	1.994	.565	.002198	.230	.01323
.47	1.477	.1735	.1230	2.082	.590	.00240	.235	.01381
.48	1.508	.1810	.1257	2.171	.615	.00261	.240	.01440
.49	1.539	.1886	.1283	2.263	.641	.00283	.245	.01501
.50	1.571	.1963	.1309	2.356	.668	.00307	.250	.01563

Properties of Tubes and Round Bars (Continued) .50 inch 1.00 inch

For Tubes use differences for A, W, I and V (for volume of wall only), sum for R^2, and direct tabular values for C, S, y and V (for capacity). For Round Bars use all tabular values direct.

Diam. in inches D	Circumference in inches C	Area cross section sq. in. A	Per foot length: Surface sq. ft. S	Per foot length: Volume cu. in. V	Per foot length: Weight, lbs. steel W	Moment of inertia I	Distance from axis to farthest fiber y	Radius of gyration squared R^2
.50	1.571	.1963	.1309	2.356	.668	.00307	.250	.01563
.51	1.602	.2043	.1335	2.451	.694	.00332	.255	.01626
.52	1.634	.2124	.1361	2.548	.722	.00359	.260	.01690
.53	1.665	.2206	.1388	2.647	.750	.00387	.265	.01756
.54	1.696	.2290	.1414	2.748	.779	.00417	.270	.01823
.55	1.728	.2376	.1440	2.851	.808	.00449	.275	.01891
.56	1.759	.2463	.1466	2.956	.837	.00483	.280	.01960
.57	1.791	.2552	.1492	3.062	.867	.00518	.285	.02031
.58	1.822	.2642	.1518	3.170	.898	.00555	.290	.02103
.59	1.854	.2734	.1545	3.281	.929	.00595	.295	.02176
.60	1.885	.2827	.1571	3.393	.961	.00636	.300	.02250
.61	1.916	.2922	.1597	3.507	.994	.00680	.305	.02326
.62	1.948	.3019	.1623	3.623	1.026	.00725	.310	.02403
.63	1.979	.3117	.1649	3.741	1.060	.00773	.315	.02481
.64	2.011	.3217	.1676	3.860	1.094	.00824	.320	.02560
.65	2.042	.3318	.1702	3.982	1.128	.00876	.325	.02641
.66	2.073	.3421	.1728	4.105	1.163	.00931	.330	.02723
.67	2.105	.3526	.1754	4.231	1.199	.00989	.335	.02806
.68	2.136	.3632	.1780	4.358	1.235	.01050	.340	.02890
.69	2.168	.3739	.1806	4.487	1.271	.01113	.345	.02976
.70	2.199	.3848	.1833	4.618	1.308	.01179	.350	.03063
.71	2.231	.3959	.1859	4.751	1.346	.01247	.355	.03151
.72	2.262	.4072	.1885	4.886	1.384	.01319	.360	.03240
.73	2.293	.4185	.1911	5.022	1.423	.01394	.365	.03331
.74	2.325	.4301	.1937	5.161	1.462	.01472	.370	.03423
.75	2.356	.4418	.1963	5.301	1.502	.01553	.375	.03516
.76	2.388	.4536	.1990	5.444	1.542	.01638	.380	.03610
.77	2.419	.4657	.2016	5.588	1.583	.01726	.385	.03706
.78	2.450	.4778	.2042	5.734	1.624	.01817	.390	.03803
.79	2.482	.4902	.2068	5.882	1.666	.01912	.395	.03901
.80	2.513	.5027	.2094	6.032	1.709	.02011	.400	.04000
.81	2.545	.5153	.2121	6.184	1.752	.02113	.405	.04101
.82	2.576	.5281	.2147	6.337	1.795	.02219	.410	.04203
.83	2.608	.5411	.2173	6.493	1.839	.02330	.415	.04306
.84	2.639	.5542	.2199	6.650	1.884	.02444	.420	.04410
.85	2.670	.5675	.2225	6.809	1.929	.02562	.425	.04516
.86	2.702	.5809	.2251	6.971	1.975	.02685	.430	.04623
.87	2.733	.5945	.2278	7.134	2.021	.02812	.435	.04731
.88	2.765	.6082	.2304	7.299	2.068	.02944	.440	.04840
.89	2.796	.6221	.2330	7.465	2.115	.03080	.445	.04951
.90	2.827	.6362	.2356	7.634	2.163	.03221	.450	.05063
.91	2.859	.6504	.2382	7.805	2.211	.03366	.455	.05176
.92	2.890	.6648	.2409	7.977	2.260	.03517	.460	.05290
.93	2.922	.6793	.2435	8.151	2.309	.03672	.465	.05406
.94	2.953	.6940	.2461	8.328	2.359	.03832	.470	.05523
.95	2.985	.7088	.2487	8.506	2.410	.03998	.475	.05641
.96	3.016	.7238	.2513	8.686	2.461	.04169	.480	.05760
.97	3.047	.7390	.2539	8.868	2.512	.04346	.485	.05881
.98	3.079	.7543	.2566	9.052	2.564	.04528	.490	.06003
.99	3.110	.7698	.2592	9.237	2.617	.04715	.495	.06126
1.00	3.142	.7854	.2618	9.425	2.670	.04909	.500	.06250

Properties of Tubes and Round Bars (Continued) **1.00** inch **1.50** inches

For Tubes use differences for A, W, I and V (for volume of wall only), sum for R^2, and direct tabular values for C, S, y and V (for capacity). For Round Bars use all tabular values direct.

Diam. in inches	Circum- ference in inches	Area cross section sq. in.	Per foot length			Moment of inertia	Distance from axis to farth- est fiber	Radius of gyra- tion squared
			Surface sq. ft.	Volume cu. in.	Weight, lbs. steel			
D	C	A	S	V	W	I	y	R^2
1.00	3.142	.7854	.2618	9.425	2.670	.04909	.500	.06250
1.01	3.173	.8012	.2644	9.614	2.724	.0511	.505	.06376
1.02	3.204	.8171	.2670	9.806	2.778	.0531	.510	.06503
1.03	3.236	.8332	.2697	9.999	2.833	.0552	.515	.06631
1.04	3.267	.8495	.2723	10.194	2.888	.0574	.520	.06760
1.05	3.299	.8659	.2749	10.391	2.944	.0597	.525	.06891
1.06	3.330	.8825	.2775	10.59	3.000	.0620	.530	.07023
1.07	3.362	.8992	.2801	10.79	3.057	.0643	.535	.07156
1.08	3.393	.9161	.2827	10.99	3.114	.0668	.540	.07290
1.09	3.424	.9331	.2854	11.20	3.172	.0693	.545	.07426
1.10	3.456	.9503	.2880	11.40	3.231	.0719	.550	.07563
1.11	3.487	.9677	.2906	11.61	3.290	.0745	.555	.07701
1.12	3.519	.9852	.2932	11.82	3.349	.0772	.560	.07840
1.13	3.550	1.0029	.2958	12.03	3.409	.0800	.565	.07981
1.14	3.581	1.0207	.2985	12.25	3.470	.0829	.570	.08123
1.15	3.613	1.0387	.3011	12.46	3.531	.0859	.575	.08266
1.16	3.644	1.0568	.3037	12.68	3.593	.0889	.580	.08410
1.17	3.676	1.0751	.3063	12.90	3.655	.0920	.585	.08556
1.18	3.707	1.0936	.3089	13.12	3.718	.0952	.590	.08703
1.19	3.738	1.1122	.3115	13.35	3.781	.0984	.595	.08851
1.20	3.770	1.1310	.3142	13.57	3.845	.1018	.600	.09000
1.21	3.801	1.1499	.3168	13.80	3.909	.1052	.605	.09151
1.22	3.833	1.1690	.3194	14.03	3.974	.1087	.610	.09303
1.23	3.864	1.1882	.3220	14.26	4.040	.1124	.615	.09456
1.24	3.896	1.2076	.3246	14.49	4.105	.1161	.620	.09610
1.25	3.927	1.2272	.3272	14.73	4.172	.1198	.625	.09766
1.26	3.958	1.2469	.3299	14.96	4.239	.1237	.630	.09923
1.27	3.990	1.2668	.3325	15.20	4.307	.1277	.635	.10081
1.28	4.021	1.287	.3351	15.44	4.375	.1318	.640	.10240
1.29	4.053	1.307	.3377	15.68	4.443	.1359	.645	.10401
1.30	4.084	1.327	.3403	15.93	4.512	.1402	.650	.10563
1.31	4.115	1.348	.3430	16.17	4.582	.1446	.655	.10726
1.32	4.147	1.368	.3456	16.42	4.652	.1490	.660	.10890
1.33	4.178	1.389	.3482	16.67	4.723	.1536	.665	.11056
1.34	4.210	1.410	.3508	16.92	4.794	.1583	.670	.11223
1.35	4.241	1.431	.3534	17.18	4.866	.1630	.675	.11391
1.36	4.273	1.453	.3560	17.43	4.939	.1679	.680	.11560
1.37	4.304	1.474	.3587	17.69	5.011	.1729	.685	.11731
1.38	4.335	1.496	.3613	17.95	5.085	.1780	.690	.11903
1.39	4.367	1.517	.3639	18.21	5.159	.1832	.695	.12076
1.40	4.398	1.539	.3665	18.47	5.233	.1886	.700	.12250
1.41	4.430	1.561	.3691	18.74	5.308	.1940	.705	.12426
1.42	4.461	1.584	.3718	19.00	5.384	.1996	.710	.12603
1.43	4.492	1.606	.3744	19.27	5.460	.2053	.715	.12781
1.44	4.524	1.629	.3770	19.54	5.537	.2111	.720	.12960
1.45	4.555	1.651	.3796	19.82	5.614	.2170	.725	.13141
1.46	4.587	1.674	.3822	20.09	5.691	.2230	.730	.13323
1.47	4.618	1.697	.3848	20.37	5.770	.2292	.735	.13506
1.48	4.650	1.720	.3875	20.64	5.848	.2355	.740	.13690
1.49	4.681	1.744	.3901	20.92	5.928	.2419	.745	.13876
1.50	4.712	1.767	.3927	21.21	6.008	.2485	.750	.14063

Properties of Tubes and Round Bars (Continued) 1.50 inches 2.00 inches

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches *D*	Circumference in inches *C*	Area cross section, sq. in. *A*	Per foot length: Surface sq. ft. *S*	Volume cu. in. *V*	Weight, lbs. steel *W*	Moment of inertia *I*	Distance from axis to farthest fiber *y*	Radius of gyration squared R^2
1.50	4.712	1.767	.3927	21.21	6.008	.2485	.750	.14063
1.51	4.744	1.791	.3953	21.49	6.088	.2552	.755	.14251
1.52	4.775	1.815	.3979	21.78	6.169	.2620	.760	.14440
1.53	4.807	1.839	.4006	22.06	6.250	.2690	.765	.14631
1.54	4.838	1.863	.4032	22.35	6.332	.2761	.770	.14823
1.55	4.869	1.887	.4058	22.64	6.415	.2833	.775	.15016
1.56	4.901	1.911	.4084	22.94	6.498	.2907	.780	.15210
1.57	4.932	1.936	.4110	23.23	6.581	.2982	.785	.15406
1.58	4.964	1.961	.4136	23.53	6.665	.3059	.790	.15603
1.59	4.995	1.986	.4163	23.83	6.750	.3137	.795	.15801
1.60	5.027	2.011	.4189	24.13	6.835	.3217	.800	.1600
1.61	5.058	2.036	.4215	24.43	6.921	.3298	.805	.1620
1.62	5.089	2.061	.4241	24.73	7.007	.3381	.810	.1640
1.63	5.121	2.087	.4267	25.04	7.094	.3465	.815	.1661
1.64	5.152	2.112	.4294	25.35	7.181	.3551	.820	.1681
1.65	5.184	2.138	.4320	25.66	7.269	.3638	.825	.1702
1.66	5.215	2.164	.4346	25.97	7.358	.3727	.830	.1722
1.67	5.246	2.190	.4372	26.28	7.446	.3818	.835	.1743
1.68	5.278	2.217	.4398	26.60	7.536	.3910	.840	.1764
1.69	5.309	2.243	.4424	26.92	7.626	.4004	.845	.1785
1.70	5.341	2.270	.4451	27.24	7.716	.4100	.850	.1806
1.71	5.372	2.297	.4477	27.56	7.807	.4197	.855	.1828
1.72	5.404	2.324	.4503	27.88	7.899	.4296	.860	.1849
1.73	5.435	2.351	.4529	28.21	7.991	.4397	.865	.1871
1.74	5.466	2.378	.4555	28.53	8.084	.4500	.870	.1892
1.75	5.498	2.405	.4581	28.86	8.177	.4604	.875	.1914
1.76	5.529	2.433	.4608	29.19	8.271	.4710	.880	.1936
1.77	5.561	2.461	.4634	29.53	8.365	.4818	.885	.1958
1.78	5.592	2.488	.4660	29.86	8.460	.4928	.890	.1980
1.79	5.623	2.516	.4686	30.20	8.555	.5039	.895	.2003
1.80	5.655	2.545	.4712	30.54	8.651	.5153	.900	.2025
1.81	5.686	2.573	.4739	30.88	8.747	.5268	.905	.2048
1.82	5.718	2.602	.4765	31.22	8.844	.5386	.910	.2070
1.83	5.749	2.630	.4791	31.56	8.942	.5505	.915	.2093
1.84	5.781	2.659	.4817	31.91	9.040	.5627	.920	.2116
1.85	5.812	2.688	.4843	32.26	9.138	.5750	.925	.2139
1.86	5.843	2.717	.4869	32.61	9.237	.5875	.930	.2162
1.87	5.875	2.746	.4896	32.96	9.337	.6003	.935	.2186
1.88	5.906	2.776	.4922	33.31	9.437	.6132	.940	.2209
1.89	5.938	2.806	.4948	33.67	9.538	.6263	.945	.2233
1.90	5.969	2.835	.4974	34.02	9.639	.6397	.950	.2256
1.91	6.000	2.865	.5000	34.38	9.741	.6533	.955	.2280
1.92	6.032	2.895	.5027	34.74	9.843	.6671	.960	.2304
1.93	6.063	2.926	.5053	35.11	9.946	.6811	.965	.2328
1.94	6.095	2.956	.5079	35.47	10.049	.6953	.970	.2352
1.95	6.126	2.986	.5105	35.84	10.153	.7098	.975	.2377
1.96	6.158	3.017	.5131	36.21	10.257	.7244	.980	.2401
1.97	6.189	3.048	.5157	36.58	10.362	.7393	.985	.2426
1.98	6.220	3.079	.5184	36.95	10.468	.7544	.990	.2450
1.99	6.252	3.110	.5210	37.32	10.574	.7698	.995	.2475
2.00	6.283	3.142	.5236	37.70	10.680	.7854	1.000	.2500

Properties of Tubes and Round Bars (Continued) **2.00** inches **2.50** inches

For Tubes use differences for A, W, I and V (for volume of wall only), sum for R^2, and direct tabular values for C, S, y and V (for capacity). For Round Bars use all tabular values direct.

Diam. in inches	Circumference in inches	Area cross section sq. in.	Per foot length			Moment of inertia	Distance from axis to farthest fiber	Radius of gyration squared
			Surface sq. ft.	Volume cu. in.	Weight, lbs. steel			
D	C	A	S	V	W	I	y	R^2
2.00	6.283	3.142	.5236	37.70	10.680	.7854	1.000	.2500
2.01	6.315	3.173	.5262	38.08	10.787	.8012	1.005	.2525
2.02	6.346	3.205	.5288	38.46	10.895	.8173	1.010	.2550
2.03	6.377	3.237	.5315	38.84	11.003	.8336	1.015	.2576
2.04	6.409	3.269	.5341	39.22	11.112	.8501	1.020	.2601
2.05	6.440	3.301	.5367	39.61	11.221	.8669	1.025	.2627
2.06	6.472	3.333	.5393	39.99	11.331	.8840	1.030	.2652
2.07	6.503	3.365	.5419	40.38	11.441	.9013	1.035	.2678
2.08	6.535	3.398	.5445	40.78	11.552	.9188	1.040	.2704
2.09	6.566	3.431	.5472	41.17	11.663	.9366	1.045	.2730
2.10	6.597	3.464	.5498	41.56	11.775	.9547	1.050	.2756
2.11	6.629	3.497	.5524	41.96	11.887	.9730	1.055	.2783
2.12	6.660	3.530	.5550	42.36	12.000	.9915	1.060	.2809
2.13	6.692	3.563	.5576	42.76	12.114	1.0104	1.065	.2836
2.14	6.723	3.597	.5603	43.16	12.228	1.0295	1.070	.2862
2.15	6.754	3.631	.5629	43.57	12.342	1.0489	1.075	.2889
2.16	6.786	3.664	.5655	43.97	12.457	1.0685	1.080	.2916
2.17	6.817	3.698	.5681	44.38	12.573	1.088	1.085	.2943
2.18	6.849	3.733	.5707	44.79	12.689	1.109	1.090	.2970
2.19	6.880	3.767	.5733	45.20	12.806	1.129	1.095	.2998
2.20	6.912	3.801	.5760	45.62	12.923	1.150	1.100	.3025
2.21	6.943	3.836	.5786	46.03	13.041	1.171	1.105	.3053
2.22	6.974	3.871	.5812	46.45	13.159	1.192	1.110	.3080
2.23	7.006	3.906	.5838	46.87	13.278	1.214	1.115	.3108
2.24	7.037	3.941	.5864	47.29	13.397	1.236	1.120	.3136
2.25	7.069	3.976	.5890	47.71	13.517	1.258	1.125	.3164
2.26	7.100	4.011	.5917	48.14	13.637	1.281	1.130	.3192
2.27	7.131	4.047	.5943	48.56	13.758	1.303	1.135	.3221
2.28	7.163	4.083	.5969	48.99	13.880	1.327	1.140	.3249
2.29	7.194	4.119	.5995	49.42	14.002	1.350	1.145	.3278
2.30	7.226	4.155	.6021	49.86	14.125	1.374	1.150	.3306
2.31	7.257	4.191	.6048	50.29	14.248	1.398	1.155	.3335
2.32	7.288	4.227	.6074	50.73	14.371	1.422	1.160	.3364
2.33	7.320	4.264	.6100	51.17	14.495	1.447	1.165	.3393
2.34	7.351	4.301	.6126	51.61	14.620	1.472	1.170	.3422
2.35	7.383	4.337	.6152	52.05	14.745	1.497	1.175	.3452
2.36	7.414	4.374	.6178	52.49	14.871	1.523	1.180	.3481
2.37	7.446	4.412	.6205	52.94	14.997	1.549	1.185	.3511
2.38	7.477	4.449	.6231	53.39	15.124	1.575	1.190	.3540
2.39	7.508	4.486	.6257	53.84	15.252	1.602	1.195	.3570
2.40	7.540	4.524	.6283	54.29	15.379	1.629	1.200	.3600
2.41	7.571	4.562	.6309	54.74	15.508	1.656	1.205	.3630
2.42	7.603	4.600	.6336	55.20	15.637	1.684	1.210	.3660
2.43	7.634	4.638	.6362	55.65	15.766	1.712	1.215	.3691
2.44	7.665	4.676	.6388	56.11	15.896	1.740	1.220	.3721
2.45	7.697	4.714	.6414	56.57	16.027	1.769	1.225	.3752
2.46	7.728	4.753	.6440	57.03	16.158	1.798	1.230	.3782
2.47	7.760	4.792	.6466	57.50	16.290	1.827	1.235	.3813
2.48	7.791	4.831	.6493	57.97	16.422	1.857	1.240	.3844
2.49	7.823	4.870	.6519	58.43	16.555	1.887	1.245	.3875
2.50	7.854	4.909	.6545	58.90	16.688	1.917	1.250	.3906

Properties of Tubes and Round Bars (Continued) **2.50** inches **3.00** inches

For Tubes use differences for A, W, I and V (for volume of wall only), sum for R^2, and direct tabular values for C, S, y and V (for capacity). For Round Bars use all tabular values direct.

Diam. in inches D	Circumference in inches C	Area cross section sq. in. A	Per foot length: Surface sq. ft. S	Per foot length: Volume cu. in. V	Per foot length: Weight, lbs. steel W	Moment of inertia I	Distance from axis to farthest fiber y	Radius of gyration squared R^2
2.50	7.854	4.909	.6545	58.90	16.688	1.917	1.250	.3906
2.51	7.885	4.948	.6571	59.38	16.822	1.948	1.255	.3938
2.52	7.917	4.988	.6597	59.85	16.956	1.980	1.260	.3969
2.53	7.948	5.027	.6624	60.33	17.091	2.011	1.265	.4001
2.54	7.980	5.067	.6650	60.80	17.226	2.043	1.270	.4032
2.55	8.011	5.107	.6676	61.28	17.362	2.076	1.275	.4064
2.56	8.042	5.147	.6702	61.77	17.498	2.108	1.280	.4096
2.57	8.074	5.187	.6728	62.25	17.635	2.141	1.285	.4128
2.58	8.105	5.228	.6754	62.74	17.773	2.175	1.290	.4160
2.59	8.137	5.269	.6781	63.22	17.911	2.209	1.295	.4193
2.60	8.168	5.309	.6807	63.71	18.049	2.243	1.300	.4225
2.61	8.200	5.350	.6833	64.20	18.189	2.278	1.305	.4258
2.62	8.231	5.391	.6859	64.70	18.328	2.313	1.310	.4290
2.63	8.262	5.433	.6885	65.19	18.468	2.349	1.315	.4323
2.64	8.294	5.474	.6912	65.69	18.609	2.384	1.320	.4356
2.65	8.325	5.515	.6938	66.19	18.750	2.421	1.325	.4389
2.66	8.357	5.557	.6964	66.69	18.892	2.458	1.330	.4422
2.67	8.388	5.599	.6990	67.19	19.034	2.495	1.335	.4456
2.68	8.419	5.641	.7016	67.69	19.177	2.532	1.340	.4489
2.69	8.451	5.683	.7042	68.20	19.321	2.570	1.345	.4523
2.70	8.482	5.726	.7069	68.71	19.465	2.609	1.350	.4556
2.71	8.514	5.768	.7095	69.22	19.609	2.648	1.355	.4590
2.72	8.545	5.811	.7121	69.73	19.754	2.687	1.360	.4624
2.73	8.577	5.853	.7147	70.24	19.900	2.727	1.365	.4658
2.74	8.608	5.896	.7173	70.76	20.046	2.767	1.370	.4692
2.75	8.639	5.940	.7199	71.27	20.192	2.807	1.375	.4727
2.76	8.671	5.983	.7226	71.79	20.339	2.848	1.380	.4761
2.77	8.702	6.026	.7252	72.32	20.487	2.890	1.385	.4796
2.78	8.734	6.070	.7278	72.84	20.635	2.932	1.390	.4830
2.79	8.765	6.114	.7304	73.36	20.784	2.974	1.395	.4865
2.80	8.796	6.158	.7330	73.89	20.933	3.017	1.400	.4900
2.81	8.828	6.202	.7357	74.42	21.083	3.061	1.405	.4935
2.82	8.859	6.246	.7383	74.95	21.233	3.104	1.410	.4970
2.83	8.891	6.290	.7409	75.48	21.384	3.149	1.415	.5006
2.84	8.922	6.335	.7435	76.02	21.535	3.193	1.420	.5041
2.85	8.954	6.379	.7461	76.55	21.687	3.239	1.425	.5077
2.86	8.985	6.424	.7487	77.09	21.840	3.284	1.430	.5112
2.87	9.016	6.469	.7514	77.63	21.993	3.330	1.435	.5148
2.88	9.048	6.514	.7540	78.17	22.146	3.377	1.440	.5184
2.89	9.079	6.560	.7566	78.72	22.300	3.424	1.445	.5220
2.90	9.111	6.605	.7592	79.26	22.455	3.472	1.450	.5256
2.91	9.142	6.651	.7618	79.81	22.610	3.520	1.455	.5293
2.92	9.173	6.697	.7645	80.36	22.766	3.569	1.460	.5329
2.93	9.205	6.743	.7671	80.91	22.922	3.618	1.465	.5366
2.94	9.236	6.789	.7697	81.46	23.079	3.667	1.470	.5402
2.95	9.268	6.835	.7723	82.02	23.236	3.718	1.475	.5439
2.96	9.299	6.881	.7749	82.58	23.394	3.768	1.480	.5476
2.97	9.331	6.928	.7775	83.14	23.552	3.819	1.485	.5513
2.98	9.362	6.975	.7802	83.70	23.711	3.871	1.490	.5550
2.99	9.393	7.022	.7828	84.26	23.870	3.923	1.495	.5588
3.00	9.425	7.069	.7854	84.82	24.030	3.976	1.500	.5625

Properties of Tubes and Round Bars (Continued) 3.00 inches 3.50 inches

For Tubes use differences for A, W, I and V (for volume of wall only), sum for R^2, and direct tabular values for C, S, y and V (for capacity). For Round Bars use all tabular values direct.

Diam. in inches D	Circumference in inches C	Area cross section sq. in. A	Per foot length: Surface sq. ft. S	Per foot length: Volume cu. in. V	Per foot length: Weight, lbs. steel W	Moment of inertia I	Distance from axis to farthest fiber y	Radius of gyration squared R^2
3.00	9.425	7.069	.7854	84.82	24.030	3.976	1.500	.5625
3.01	9.456	7.116	.7880	85.39	24.191	4.029	1.505	.5663
3.02	9.488	7.163	.7906	85.96	24.352	4.083	1.510	.5700
3.03	9.519	7.211	.7933	86.53	24.513	4.138	1.515	.5738
3.04	9.550	7.258	.7959	87.10	24.675	4.192	1.520	.5776
3.05	9.582	7.306	.7985	87.67	24.838	4.248	1.525	.5814
3.06	9.613	7.354	.8011	88.25	25.001	4.304	1.530	.5852
3.07	9.645	7.402	.8037	88.83	25.165	4.360	1.535	.5891
3.08	9.676	7.451	.8063	89.41	25.329	4.417	1.540	.5929
3.09	9.708	7.499	.8090	89.99	25.494	4.475	1.545	.5968
3.10	9.739	7.548	.8116	90.57	25.659	4.533	1.550	.6006
3.11	9.770	7.596	.8142	91.16	25.825	4.592	1.555	.6045
3.12	9.802	7.645	.8168	91.74	25.991	4.651	1.560	.6084
3.13	9.833	7.694	.8194	92.33	26.158	4.711	1.565	.6123
3.14	9.865	7.744	.8221	92.92	26.326	4.772	1.570	.6162
3.15	9.896	7.793	.8247	93.52	26.493	4.833	1.575	.6202
3.16	9.927	7.843	.8273	94.11	[illegible] 662	4.895	1.580	.6241
3.17	9.959	7.892	.8299	94.71	[illegible] 831	4.957	1.585	[illegible]
3.18	9.990	7.942	.8325	95.31	27.001	5.020	1.590	.6320
3.19	10.022	7.992	.8351	95.91	27.171	5.083	1.595	.6360
3.20	10.053	8.042	.8378	96.51	27.341	5.147	1.600	.6400
3.21	10.085	8.093	.8404	97.11	27.512	5.212	1.605	.6440
3.22	10.116	8.143	.8430	97.72	27.684	5.277	1.610	.6480
3.23	10.147	8.194	.8456	98.33	27.856	5.343	1.615	.6521
3.24	10.179	8.245	.8482	98.94	28.029	5.409	1.620	.6561
3.25	10.210	8.296	.8508	99.55	28.202	5.477	1.625	.6602
3.26	10.242	8.347	.8535	100.16	28.376	5.544	1.630	.6642
3.27	10.273	8.398	.8561	100.78	28.550	5.613	1.635	.6683
3.28	10.304	8.450	.8587	101.40	28.725	5.682	1.640	.6724
3.29	10.336	8.501	.8613	102.01	28.901	5.751	[illegible]	.6765
3.30	10.367	8.553	.8639	102.64	29.077	5.821	1.650	.6806
3.31	10.399	8.605	.8666	103.26	29.253	5.892	1.655	.6848
3.32	10.430	8.657	.8692	103.88	29.430	5.964	..	.6889
3.33	10.462	8.709	.8718	104.51	29.608	6.036		.6931
3.34	10.493	8.762	.8744	105.14	29.786	6.109		.6972
3.35	10.524	8.814	.8770	105.77	[illegible] 965	6.182		.7014
3.36	10.556	8.867	.8796	106.40	30.144	6.256		.7056
3.37	10.587	8.920	.8823	107.04	30.323	6.331		.7098
3.38	10.619	8.973	.8849	107.67	30.504	6.407		.7140
3.39	10.650	9.026	.8875	108.31	30.684	6.483		.7183
3.40	10.681	9.079	.8901	108.95	30.866	6.560	1.700	.7225
3.41	10.713	9.133	.8927	109.59	31.047	6.637	1.705	.7268
3.42	10.744	9.186	.8954	110.24	31.230	6.715	1.710	.7310
3.43	10.776	9.240	.8980	110.88	31.413	6.794	1.715	.7353
3.44	10.807	9.294	.9006	111.53	31.596	6.874	1.720	.7396
3.45	10.838	9.348	.9032	112.18	31.780	6.954	1.725	.7439
3.46	10.870	9.402	.9058	112.83	31.965	7.035	1.730	.7482
3.47	10.901	9.457	.9084	113.48	32.150	7.117	1.735	.7526
3.48	10.933	9.511	.9111	114.14	32.335	7.199	1.740	.7569
3.49	10.964	9.566	.9137	114.79	32.521	7.282	1.745	.7613
3.50	10.996	9.621	.9163	115.45	32.708	7.366	1.750	.7656

Properties of Tubes and Round Bars (Continued) **3.50** inches **4.00** inches

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches *D*	Circumference in inches *C*	Area cross section sq. in. *A*	Per foot length: Surface sq. ft. *S*	Per foot length: Volume cu. in. *V*	Per foot length: Weight, lbs. steel *W*	Moment of inertia *I*	Distance from axis to farthest fiber *y*	Radius of gyration squared R^2
3.50	10.996	9.621	.9163	115.45	32.708	7.366	1.750	.7656
3.51	11.027	9.676	.9189	116.11	32.895	7.451	1.755	.7700
3.52	11.058	9.731	.9215	116.78	33.083	7.536	1.760	.7744
3.53	11.090	9.787	.9242	117.44	33.271	7.622	1.765	.7788
3.54	11.121	9.842	.9268	118.11	33.460	7.709	1.770	.7832
3.55	11.153	9.898	.9294	118.78	33.649	7.796	1.775	.7877
3.56	11.184	9.954	.9320	119.45	33.839	7.884	1.780	.7921
3.57	11.215	10.010	.9346	120.12	34.029	7.973	1.785	.7966
3.58	11.247	10.066	.9372	120.79	34.220	8.063	1.790	.8010
3.59	11.278	10.122	.9399	121.47	34.412	8.154	1.795	.8055
3.60	11.310	10.179	.9425	122.15	34.604	8.245	1.800	.8100
3.61	11.341	10.235	.9451	122.82	34.796	8.337	1.805	.8145
3.62	11.373	10.292	.9477	123.51	34.989	8.430	1.810	.8190
3.63	11.404	10.349	.9503	124.19	35.183	8.523	1.815	.8236
3.64	11.435	10.406	.9529	124.87	35.377	8.617	1.820	.8281
3.65	11.467	10.463	.9556	125.56	35.572	8.712	1.825	.8327
3.66	11.498	10.521	.9582	126.25	35.767	8.808	1.830	.8372
3.67	11.530	10.578	.9608	126.94	35.962	8.905	1.835	.8418
3.68	11.561	10.636	.9634	127.63	36.159	9.002	1.840	.8464
3.69	11.592	10.694	.9660	128.33	36.356	9.101	1.845	.8510
3.70	11.624	10.752	.9687	129.03	36.553	9.200	1.850	.8556
3.71	11.655	10.810	.9713	129.72	36.751	9.300	1.855	.8603
3.72	11.687	10.869	.9739	130.42	36.949	9.400	1.860	.8649
3.73	11.718	10.927	.9765	131.13	37.148	9.502	1.865	.8696
3.74	11.750	10.986	.9791	131.83	37.347	9.604	1.870	.8742
3.75	11.781	11.045	.9817	132.54	37.55	9.707	1.875	.8789
3.76	11.812	11.104	.9844	133.24	37.75	9.811	1.880	.8836
3.77	11.844	11.163	.9870	133.95	37.95	9.916	1.885	.8883
3.78	11.875	11.222	.9896	134.66	38.15	10.022	1.890	.8930
3.79	11.907	11.282	.9922	135.38	38.35	10.128	1.895	.8978
3.80	11.938	11.341	.9948	136.09	38.56	10.235	1.900	.9025
3.81	11.969	11.401	.9975	136.81	38.76	10.344	1.905	.9073
3.82	12.001	11.461	1.0001	137.53	38.96	10.453	1.910	.9120
3.83	12.032	11.521	1.0027	138.25	39.17	10.562	1.915	.9168
3.84	12.064	11.581	1.0053	138.97	39.37	10.673	1.920	.9216
3.85	12.095	11.642	1.0079	139.70	39.58	10.785	1.925	.9264
3.86	12.127	11.702	1.0105	140.43	39.78	10.897	1.930	.9312
3.87	12.158	11.763	1.0132	141.15	39.99	11.011	1.935	.9361
3.88	12.189	11.824	1.0158	141.88	40.20	11.125	1.940	.9409
3.89	12.221	11.885	1.0184	142.62	40.40	11.240	1.945	.9458
3.90	12.252	11.946	1.0210	143.35	40.61	11.356	1.950	.9506
3.91	12.284	12.007	1.0236	144.09	40.82	11.473	1.955	.9555
3.92	12.315	12.069	1.0263	144.82	41.03	11.591	1.960	.9604
3.93	12.346	12.130	1.0289	145.56	41.24	11.710	1.965	.9653
3.94	12.378	12.192	1.0315	146.31	41.45	11.829	1.970	.9702
3.95	12.409	12.254	1.0341	147.05	41.66	11.950	1.975	.9752
3.96	12.441	12.316	1.0367	147.80	41.87	12.071	1.980	.9801
3.97	12.472	12.379	1.0393	148.54	42.08	12.194	1.985	.9851
3.98	12.504	12.441	1.0420	149.29	42.29	12.317	1.990	.9900
3.99	12.535	12.504	1.0446	150.04	42.51	12.441	1.995	.9950
4.00	12.566	12.566	1.0472	150.80	42.72	12.566	2.000	1.0000

Properties of Tubes and Round Bars (Continued) **4.00 inches 4.50 inches**

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches *D*	Circumference in inches *C*	Area cross section sq. in. *A*	Per foot length: Surface sq. ft. *S*	Per foot length: Volume cu. in. *V*	Per foot length: Weight, lbs. steel *W*	Moment of inertia *I*	Distance from axis to farthest fiber *y*	Radius of gyration squared R^2
4.00	12.566	12.566	1.0472	150.80	42.72	12.566	2.000	1.0000
4.01	12.598	12.629	1.0498	151.55	42.93	12.693	2.005	1.0050
4.02	12.629	12.692	1.0524	152.31	43.15	12.820	2.010	1.0100
4.03	12.661	12.756	1.0551	153.07	43.36	12.948	2.015	1.0151
4.04	12.692	12.819	1.0577	153.83	43.58	13.077	2.020	1.0201
4.05	12.723	12.882	1.0603	154.59	43.80	13.207	2.025	1.0252
4.06	12.755	12.946	1.0629	155.35	44.01	13.338	2.030	1.0302
4.07	12.786	13.010	1.0655	156.12	44.23	13.469	2.035	1.0353
4.08	12.818	13.074	1.0681	156.89	44.45	13.602	2.040	1.0404
4.09	12.849	13.138	1.0708	157.66	44.66	13.736	2.045	1.0455
4.10	12.881	13.203	1.0734	158.43	44.88	13.871	2.050	1.0506
4.11	12.912	13.267	1.0760	159.20	45.10	14.007	2.055	1.0558
4.12	12.943	13.332	1.0786	159.98	45.32	14.144	2.060	1.0609
4.13	12.975	13.396	1.0812	160.76	45.54	14.281	2.065	1.0661
4.14	13.006	13.461	1.0838	161.54	45.76	14.420	2.070	1.0712
4.15	13.038	13.527	1.0865	162.32	45.98	14.560	2.075	1.0764
4.16	13.069	13.592	1.0891	163.10	46.21	14.701	2.080	1.0816
4.17	13.100	13.657	1.0917	163.89	46.43	14.843	2.085	1.0868
4.18	13.132	13.723	1.0943	164.67	46.65	14.986	2.090	1.0920
4.19	13.163	13.789	1.0969	165.46	46.88	15.130	2.095	1.0973
4.20	13.195	13.854	1.0996	166.25	47.10	15.274	2.100	1.1025
4.21	13.226	13.920	1.1022	167.05	47.32	15.421	2.105	1.1078
4.22	13.258	13.987	1.1048	167.84	47.55	15.568	2.110	1.1130
4.23	13.289	14.053	1.1074	168.64	47.77	15.716	2.115	1.1183
4.24	13.320	14.120	1.1100	169.43	48.00	15.865	2.120	1.1236
4.25	13.352	14.186	1.1126	170.24	48.23	16.015	2.125	1.1289
4.26	13.383	14.253	1.1153	171.04	48.45	16.166	2.130	1.1342
4.27	13.415	14.320	1.1179	171.84	48.68	16.319	2.135	1.1396
4.28	13.446	14.387	1.1205	172.65	48.91	16.472	2.140	1.1449
4.29	13.477	14.455	1.1231	173.45	49.14	16.626	2.145	1.1503
4.30	13.509	14.522	1.1257	174.26	49.37	16.782	2.150	1.1556
4.31	13.540	14.590	1.1284	175.08	49.60	16.939	2.155	1.1610
4.32	13.572	14.657	1.1310	175.89	49.83	17.096	2.160	1.1664
4.33	13.603	14.725	1.1336	176.70	50.06	17.255	2.165	1.1718
4.34	13.635	14.793	1.1362	177.52	50.29	17.415	2.170	1.1772
4.35	13.666	14.862	1.1388	178.34	50.52	17.576	2.175	1.1827
4.36	13.697	14.930	1.1414	179.16	50.76	17.738	2.180	1.1881
4.37	13.729	14.999	1.1441	179.98	50.99	17.902	2.185	1.1936
4.38	13.760	15.067	1.1467	180.81	51.22	18.066	2.190	1.1990
4.39	13.792	15.136	1.1493	181.64	51.46	18.232	2.195	1.2045
4.40	13.823	15.205	1.1519	182.46	51.69	18.398	2.200	1.2100
4.41	13.854	15.275	1.1545	183.29	51.93	18.566	2.205	1.2155
4.42	13.886	15.344	1.1572	184.13	52.16	18.735	2.210	1.2210
4.43	13.917	15.413	1.1598	184.96	52.40	18.905	2.215	1.2266
4.44	13.949	15.483	1.1624	185.80	52.64	19.077	2.220	1.2321
4.45	13.980	15.553	1.1650	186.63	52.87	19.249	2.225	1.2377
4.46	14.012	15.623	1.1676	187.47	53.11	19.423	2.230	1.2432
4.47	14.043	15.693	1.1702	188.32	53.35	19.598	2.235	1.2488
4.48	14.074	15.763	1.1729	189.16	53.59	19.773	2.240	1.2544
4.49	14.106	15.834	1.1755	190.00	53.83	19.951	2.245	1.2600
4.50	14.137	15.904	1.1781	190.85	54.07	20.129	2.250	1.2656

Properties of Tubes and Round Bars (Continued) **4.50** inches **5.00** inches

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches *D*	Circumference in inches *C*	Area cross section sq. in. *A*	Per foot length: Surface sq. ft. *S*	Per foot length: Volume cu. in. *V*	Per foot length: Weight, lbs. steel *W*	Moment of inertia *I*	Distance from axis to farthest fiber *y*	Radius of gyration squared R^2
4.50	14.137	15.904	1.1781	190.85	54.07	20.129	2.250	1.2656
4.51	14.169	15.975	1.1807	191.70	54.31	20.309	2.255	1.2713
4.52	14.200	16.046	1.1833	192.55	54.55	20.489	2.260	1.2769
4.53	14.231	16.117	1.1860	193.40	54.79	20.671	2.265	1.2826
4.54	14.263	16.188	1.1886	194.26	55.03	20.854	2.270	1.2882
4.55	14.294	16.260	1.1912	195.12	55.28	21.039	2.275	1.2939
4.56	14.326	16.331	1.1938	195.98	55.52	21.224	2.280	1.2996
4.57	14.357	16.403	1.1964	196.84	55.76	21.411	2.285	1.3053
4.58	14.388	16.475	1.1990	197.70	56.01	21.599	2.290	1.3110
4.59	14.420	16.547	1.2017	198.56	56.25	21.788	2.295	1.3168
4.60	14.451	16.619	1.2043	199.43	56.50	21.979	2.300	1.3225
4.61	14.483	16.691	1.2069	200.30	56.74	22.171	2.305	1.3283
4.62	14.514	16.764	1.2095	201.17	56.99	22.364	2.310	1.3340
4.63	14.546	16.837	1.2121	202.04	57.24	22.558	2.315	1.3398
4.64	14.577	16.909	1.2147	202.91	57.48	22.753	2.320	1.3456
4.65	14.608	16.982	1.2174	203.79	57.73	22.950	2.325	1.3514
4.66	14.640	17.055	1.2200	204.66	57.98	23.148	2.330	1.3572
4.67	14.671	17.129	1.2226	205.54	58.23	23.35	2.335	1.3631
4.68	14.703	17.202	1.2252	206.43	58.48	23.55	2.340	1.3689
4.69	14.734	17.276	1.2273	207.31	58.73	23.75	2.345	1.3748
4.70	14.765	17.349	1.2305	208.19	58.98	23.95	2.350	1.3806
4.71	14.797	17.423	1.2331	209.08	59.23	24.16	2.355	1.3865
4.72	14.828	17.497	1.2357	209.97	59.48	24.36	2.360	1.3924
4.73	14.860	17.572	1.2383	210.86	59.74	24.57	2.365	1.3983
4.74	14.891	17.646	1.2409	211.75	59.99	24.78	2.370	1.4042
4.75	14.923	17.721	1.2435	212.65	60.24	24.99	2.375	1.4102
4.76	14.954	17.795	1.2462	213.54	60.50	25.20	2.380	1.4161
4.77	14.985	17.870	1.2488	214.44	60.75	25.41	2.385	1.4221
4.78	15.017	17.945	1.2514	215.34	61.01	25.63	2.390	1.4280
4.79	15.048	18.020	1.2540	216.24	61.26	25.84	2.395	1.4340
4.80	15.080	18.096	1.2566	217.15	61.52	26.06	2.400	1.4400
4.81	15.111	18.171	1.2593	218.05	61.77	26.28	2.405	1.4460
4.82	15.142	18.247	1.2619	218.96	62.03	26.49	2.410	1.4520
4.83	15.174	18.322	1.2645	219.87	62.29	26.72	2.415	1.4581
4.84	15.205	18.398	1.2671	220.78	62.55	26.94	2.420	1.4641
4.85	15.237	18.475	1.2697	221.69	62.81	27.16	2.425	1.4702
4.86	15.268	18.551	1.2723	222.61	63.07	27.39	2.430	1.4762
4.87	15.300	18.627	1.2750	223.53	63.33	27.61	2.435	1.4823
4.88	15.331	18.704	1.2776	224.45	63.59	27.84	2.440	1.4884
4.89	15.362	18.781	1.2802	225.37	63.85	28.07	2.445	1.4945
4.90	15.394	18.857	1.2828	226.29	64.11	28.30	2.450	1.5006
4.91	15.425	18.934	1.2854	227.21	64.37	28.53	2.455	1.5068
4.92	15.457	19.012	1.2881	228.14	64.63	28.76	2.460	1.5129
4.93	15.488	19.089	1.2907	229.07	64.90	29.00	2.465	1.5191
4.94	15.519	19.167	1.2933	230.00	65.16	29.23	2.470	1.5252
4.95	15.551	19.244	1.2959	230.93	65.42	29.47	2.475	1.5314
4.96	15.582	19.322	1.2985	231.86	65.69	29.71	2.480	1.5376
4.97	15.614	19.400	1.3011	232.80	65.95	29.95	2.485	1.5438
4.98	15.645	19.478	1.3038	233.74	66.22	30.19	2.490	1.5500
4.99	15.677	19.556	1.3064	234.68	66.48	30.43	2.495	1.5563
5.00	15.708	19.635	1.3090	235.62	66.75	30.68	2.500	1.5625

Properties of Tubes and Round Bars (Continued) 5.00 inches 5.50 inches

For Tubes use differences for A, W, I and V (for volume of wall only), sum for R^2, and direct tabular values for C, S, y and V (for capacity). For Round Bars use all tabular values direct.

Diam. in inches D	Circumference in inches C	Area cross section sq. in. A	Per foot length: Surface sq. ft. S	Per foot length: Volume cu. in. V	Per foot length: Weight, lbs. steel W	Moment of inertia I	Distance from axis to farthest fiber y	Radius of gyration squared R^2
5.00	15.708	19.635	1.3090	235.62	66.75	30.68	2.500	1.5625
5.01	15.739	19.714	1.3116	236.56	67.02	30.93	2.505	1.5688
5.02	15.771	19.792	1.3142	237.51	67.29	31.17	2.510	1.5750
5.03	15.802	19.871	1.3169	238.46	67.55	31.42	2.515	1.5813
5.04	15.834	19.950	1.3195	239.40	67.82	31.67	2.520	1.5876
5.05	15.865	20.030	1.3221	240.36	68.09	31.93	2.525	1.5939
5.06	15.896	20.109	1.3247	241.31	68.36	32.18	2.530	1.6002
5.07	15.928	20.189	1.3273	242.26	68.63	32.43	2.535	1.6066
5.08	15.959	20.268	1.3299	243.22	68.90	32.69	2.540	1.6129
5.09	15.991	20.348	1.3326	244.18	69.18	32.95	2.545	1.6193
5.10	16.022	20.428	1.3352	245.14	69.45	33.21	2.550	1.6256
5.11	16.054	20.508	1.3378	246.10	69.72	33.47	2.555	1.6320
5.12	16.085	20.589	1.3404	247.06	69.99	33.73	2.560	1.6384
5.13	16.116	20.669	1.3430	248.03	70.27	34.00	2.565	1.6448
5.14	16.148	20.750	1.3456	249.00	70.54	34.26	2.570	1.6512
5.15	16.179	20.831	1.3483	249.97	70.82	34.53	2 575	1.6577
5.16	16.211	20.912	1.3509	250.94	71.09	34.80	2.580	1.6641
5.17	16.242	20.993	1.3535	251.91	71.37	35.07	2.585	1.6706
5.18	16.273	21.074	1.3561	252.89	71.64	35.34	2.590	1.6770
5.19	16.305	21.156	1.3587	253.87	71.92	35.62	2.595	1.6835
5.20	16.336	21.237	1.3614	254.85	72.20	35.89	2.600	1.6900
5.21	16.368	21.319	1.3640	255.83	72.48	36.17	2.605	1.6965
5.22	16.399	21.401	1.3666	256.81	72.75	36.45	2.610	1.7030
5.23	16.431	21.483	1.3692	257.80	73.03	36.73	2.615	1.7096
5.24	16.462	21.565	1.3718	258.78	73.31	37.01	2.620	1.7161
5.25	16.493	21.648	1.3744	259.77	73.59	37.29	2.625	1.7227
5.26	16.525	21.730	1.3771	260.76	73.87	37.58	2.630	1.7292
5.27	16.556	21.813	1.3797	261.75	74.15	37.86	2.635	1.7358
5.28	16.588	21.896	1.3823	262.75	74.44	38.15	2.640	1.7424
5.29	16.619	21.979	1.3849	263.74	74.72	38.44	2.645	1.7490
5.30	16.650	22.062	1.3875	264.74	75.00	38.73	2.650	1.7556
5.31	16.682	22.145	1.3902	265.74	75.28	39.03	2.655	1.7623
5.32	16.713	22.229	1.3928	266.74	75.57	39.32	2.660	1.7689
5.33	16.745	22.312	1.3954	267.75	75.85	39.62	2.665	1.7756
5.34	16.776	22.396	1.3980	268.75	76.14	39.92	2.670	1.7822
5.35	16.808	22.480	1.4006	269.76	76.42	40.21	2.675	1.7889
5.36	16.839	22.564	1.4032	270.77	76.71	40.52	2.680	1.7956
5.37	16.870	22.648	1.4059	271.78	77.00	40.82	2.685	1.8023
5.38	16.902	22.733	1.4085	272.79	77.28	41.12	2.690	1.8090
5.39	16.933	22.817	1.4111	273.81	77.57	41.43	2.695	1.8158
5.40	16.965	22.902	1.4137	274.83	77.86	41.74	2.700	1.8225
5.41	16.996	22.987	1.4163	275.85	78.15	42.05	2.705	1.8293
5.42	17.027	23.072	1.4190	276.87	78.44	42.36	2.710	1.8360
5.43	17.059	23.157	1.4216	277.89	78.73	42.67	2.715	1.8428
5.44	17.090	23.243	1.4242	278.91	79.02	42.99	2.720	1.8496
5.45	17.122	23.328	1.4268	279.94	79.31	43.31	2.725	1.8564
5.46	17.153	23.414	1.4294	280.97	79.60	43.63	2.730	1.8632
5.47	17.185	23.500	1.4320	282.00	79.89	43.95	2.735	1.8701
5.48	17.216	23.586	1.4347	283.03	80.18	44.27	2.740	1.8769
5.49	17.247	23.672	1.4373	284.06	80.48	44.59	2.745	1.8838
5.50	17.279	23.758	1.4399	285.10	80.77	44.92	2.750	1.8906

Properties of Tubes and Round Bars (Continued) **5.50** inche **6.00** inche

For Tubes use differences for A, W, I **and** V **(for volume of wall only), sum fo** R^2**, and direct tabular values for** C, S, y **and** V **(for capacity). For Roun Bars use all tabular values direct.**

Diam. in inches D	Circumference in inches C	Area cross section sq. in. A	Per foot length: Surface sq. ft. S	Per foot length: Volume cu. in. V	Per foot length: Weight, lbs. steel W	Moment of inertia I	Distance from axis to farthest fiber y	Radius of gyration squared R^2
5.50	17.279	23.758	1.4399	285.10	80.77	44.92	2.750	1.8906
5.51	17.310	23.845	1.4425	286.14	81.06	45.25	2.755	1.8975
5.52	17.342	23.931	1.4451	287.18	81.36	45.57	2.760	1.9044
5.53	17.373	24.018	1.4478	288.22	81.65	45.91	2.765	1.9113
5.54	17.404	24.105	1.4504	289.26	81.95	46.24	2.770	1.9182
5.55	17.436	24.192	1.4530	290.31	82.24	46.57	2.775	1.9252
5.56	17.467	24.279	1.4556	291.35	82.54	46.91	2.780	1.9321
5.57	17.499	24.367	1.4582	292.40	82.84	47.25	2.785	1.9391
5.58	17.530	24.454	1.4608	293.45	83.14	47.59	2.790	1.9460
5.59	17.562	24.542	1.4635	294.51	83.43	47.93	2.795	1.9530
5.60	17.593	24.630	1.4661	295.56	83.73	48.27	2.800	1.9600
5.61	17.624	24.718	1.4687	296.62	84.03	48.62	2.805	1.9670
5.62	17.656	24.806	1.4713	297.68	84.33	48.97	2.810	1.9740
5.63	17.687	24.895	1.4739	298.74	84.63	49.32	2.815	1.9811
5.64	17.719	24.983	1.4765	299.80	84.93	49.67	2.820	1.9881
5.65	17.750	25.072	1.4792	300.86	85.23	50.02	2.825	1.9952
5.66	17.781	25.161	1.4818	301.93	85.54	50.38	2.830	2.0022
5.67	17.813	25.250	1.4844	303.00	85.84	50.73	2.835	2.0093
5.68	17.844	25.339	1.4870	304.07	86.14	51.09	2.840	2.0164
5.69	17.876	25.428	1.4896	305.14	86.45	51.45	2.845	2.0235
5.70	17.907	25.518	1.4923	306.21	86.75	51.82	2.850	2.0306
5.71	17.938	25.607	1.4949	307.29	87.05	52.18	2.855	2.0378
5.72	17.970	25.697	1.4975	308.36	87.36	52.55	2.860	2.0449
5.73	18.001	25.787	1.5001	309.44	87.67	52.92	2.865	2.0521
5.74	18.033	25.877	1.5027	310.52	87.97	53.29	2.870	2.0592
5.75	18.064	25.967	1.5053	311.61	88.28	53.66	2.875	2.0664
5.76	18.096	26.058	1.5080	312.69	88.59	54.03	2.880	2.0736
5.77	18.127	26.148	1.5106	313.78	88.89	54.41	2.885	2.0808
5.78	18.158	26.239	1.5132	314.87	89.20	54.79	2.890	2.0880
5.79	18.190	26.330	1.5158	315.96	89.51	55.17	2.895	2.0953
5.80	18.221	26.421	1.5184	317.05	89.82	55.55	2.900	2.1025
5.81	18.253	26.512	1.5211	318.14	90.13	55.93	2.905	2.1098
5.82	18.284	26.603	1.5237	319.24	90.44	56.32	2.910	2.1170
5.83	18.315	26.695	1.5263	320.34	90.75	56.71	2.915	2.1243
5.84	18.347	26.786	1.5289	321.44	91.06	57.10	2.920	2.1316
5.85	18.378	26.878	1.5315	322.54	91.38	57.49	2.925	2.1389
5.86	18.410	26.970	1.5341	323.64	91.69	57.88	2.930	2.1462
5.87	18.441	27.062	1.5368	324.75	92.00	58.28	2.935	2.1536
5.88	18.473	27.155	1.5394	325.86	92.32	58.68	2.940	2.1609
5.89	18.504	27.247	1.5420	326.97	92.63	59.08	2.945	2.1683
5.90	18.535	27.340	1.5446	328.08	92.94	59.48	2.950	2.1756
5.91	18.567	27.432	1.5472	329.19	93.26	59.89	2.955	2.1830
5.92	18.598	27.525	1.5499	330.30	93.58	60.29	2.960	2.1904
5.93	18.630	27.618	1.5525	331.42	93.89	60.70	2.965	2.1978
5.94	18.661	27.712	1.5551	332.54	94.21	61.11	2.970	2.2052
5.95	18.692	27.805	1.5577	333.66	94.53	61.52	2.975	2.2127
5.96	18.724	27.899	1.5603	334.78	94.84	61.94	2.980	2.2201
5.97	18.755	27.992	1.5629	335.91	95.16	62.35	2.985	2.2276
5.98	18.787	28.086	1.5656	337.03	95.48	62.77	2.990	2.2350
5.99	18.818	28.180	1.5682	338.16	95.80	63.19	2.995	2.2425
6.00	18.850	28.274	1.5708	339.29	96.12	63.62	3.000	2.2500

Properties of Tubes and Round Bars (Continued) **6.00 inches 6.50 inches**

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches *D*	Circumference in inches *C*	Area cross section sq. in. *A*	Per foot length: Surface sq. ft. *S*	Per foot length: Volume cu. in. *V*	Per foot length: Weight, lbs. steel *W*	Moment of inertia *I*	Distance from axis to farthest fiber *y*	Radius of gyration squared R^2
6.00	18.850	28.274	1.5708	339.29	96.12	63.62	3.000	2.2500
6.01	18.881	28.369	1.5734	340.42	96.44	64.04	3.005	2.2575
6.02	18.912	28.463	1.5760	341.56	96.76	64.47	3.010	2.2650
6.03	18.944	28.558	1.5787	342.69	97.09	64.90	3.015	2.2726
6.04	18.975	28.653	1.5813	343.83	97.41	65.33	3.020	2.2801
6.05	19.007	28.748	1.5839	344.97	97.73	65.76	3.025	2.2877
6.06	19.038	28.843	1.5865	346.11	98.05	66.20	3.030	2.2952
6.07	19.069	28.938	1.5891	347.26	98.38	66.64	3.035	2.3028
6.08	19.101	29.033	1.5917	348.40	98.70	67.08	3.040	2.3104
6.09	19.132	29.129	1.5944	349.55	99.03	67.52	3.045	2.3180
6.10	19.164	29.225	1.5970	350.70	99.35	67.97	3.050	2.3256
6.11	19.195	29.321	1.5996	351.85	99.68	68.41	3.055	2.3333
6.12	19.227	29.417	1.6022	353.00	100.00	68.86	3.060	2.3409
6.13	19.258	29.513	1.6048	354.15	100.33	69.31	3.065	2.3486
6.14	19.289	29.609	1.6074	355.31	100.66	69.77	3.070	2.3562
6.15	19.321	29.706	1.6101	356.47	100.99	70.22	3.075	2.3639
6.16	19.352	29.802	1.6127	357.63	101.32	70.68	3.080	2.3716
6.17	19.384	29.899	1.6153	358.79	101.65	71.14	3.085	2.3793
6.18	19.415	29.996	1.6179	359.95	101.98	71.60	3.090	2.3870
6.19	19.446	30.093	1.6205	361.12	102.31	72.07	3.095	2.3948
6.20	19.478	30.191	1.6232	362.29	102.64	72.53	3.100	2.4025
6.21	19.509	30.288	1.6258	363.46	102.97	73.00	3.105	2.4103
6.22	19.541	30.386	1.6284	364.63	103.30	73.47	3.110	2.4180
6.23	19.572	30.484	1.6310	365.80	103.63	73.95	3.115	2.4258
6.24	19.604	30.582	1.6336	366.98	103.96	74.42	3.120	2.4336
6.25	19.635	30.680	1.6362	368.16	104.30	74.90	3.125	2.4414
6.26	19.666	30.778	1.6389	369.33	104.63	75.38	3.130	2.4492
6.27	19.698	30.876	1.6415	370.52	104.97	75.86	3.135	2.4571
6.28	19.729	30.975	1.6441	371.70	105.30	76.35	3.140	2.4649
6.29	19.761	31.074	1.6467	372.88	105.64	76.84	3.145	2.4728
6.30	19.792	31.172	1.6493	374.07	105.97	77.33	3.150	2.4806
6.31	19.823	31.271	1.6520	375.26	106.31	77.82	3.155	2.4885
6.32	19.855	31.371	1.6546	376.45	106.65	78.31	3.160	2.4964
6.33	19.886	31.470	1.6572	377.64	106.99	78.81	3.165	2.5043
6.34	19.918	31.570	1.6598	378.83	107.32	79.31	3.170	2.5122
6.35	19.949	31.669	1.6624	380.03	107.66	79.81	3.175	2.5202
6.36	19.981	31.769	1.6650	381.23	108.00	80.32	3.180	2.5281
6.37	20.012	31.869	1.6677	382.43	108.34	80.82	3.185	2.5361
6.38	20.043	31.969	1.6703	383.63	108.68	81.33	3.190	2.5440
6.39	20.075	32.069	1.6729	384.83	109.02	81.84	3.195	2.5520
6.40	20.106	32.170	1.6755	386.04	109.36	82.35	3.200	2.5600
6.41	20.138	32.271	1.6781	387.25	109.71	82.87	3.205	2.5680
6.42	20.169	32.371	1.6808	388.46	110.05	83.39	3.210	2.5760
6.43	20.200	32.472	1.6834	389.67	110.39	83.91	3.215	2.5841
6.44	20.232	32.573	1.6860	390.88	110.74	84.43	3.220	2.5921
6.45	20.263	32.675	1.6886	392.09	111.08	84.96	3.225	2.6002
6.46	20.295	32.776	1.6912	393.31	111.43	85.49	3.230	2.6082
6.47	20.326	32.877	1.6938	394.53	111.77	86.02	3.235	2.6163
6.48	20.358	32.979	1.6965	395.75	112.12	86.55	3.240	2.6244
6.49	20.389	33.081	1.6991	396.97	112.46	87.09	3.245	2.6325
6.50	20.420	33.183	1.7017	398.20	112.81	87.62	3.250	2.6406

Properties of Tubes and Round Bars (Continued) **6.50 inches 7.00 inches**

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches *D*	Circumference in inches *C*	Area cross section sq. in. *A*	Per foot length: Surface sq. ft. *S*	Per foot length: Volume cu. in. *V*	Per foot length: Weight, lbs. steel *W*	Moment of inertia *I*	Distance from axis to farthest fiber *y*	Radius of gyration squared R^2
6.50	20.420	33.183	1.7017	398.20	112.81	87.62	3.250	2.6406
6.51	20.452	33.285	1.7043	399.42	113.16	88.16	3.255	2.6488
6.52	20.483	33.388	1.7069	400.65	113.50	88.71	3.260	2.6569
6.53	20.515	33.490	1.7096	401.88	113.85	89.25	3.265	2.6651
6.54	20.546	33.593	1.7122	403.11	114.20	89.80	3.270	2.6732
6.55	20.577	33.696	1.7148	404.35	114.55	90.35	3.275	2.6814
6.56	20.609	33.799	1.7174	405.58	114.90	90.90	3.280	2.6896
6.57	20.640	33.902	1.7200	406.82	115.25	91.46	3.285	2.6978
6.58	20.672	34.005	1.7226	408.06	115.60	92.02	3.290	2.7060
6.59	20.703	34.108	1.7253	409.30	115.95	92.58	3.295	2.7143
6.60	20.735	34.212	1.7279	410.54	116.31	93.14	3.300	2.7225
6.61	20.766	34.316	1.7305	411.79	116.66	93.71	3.305	2.7308
6.62	20.797	34.420	1.7331	413.04	117.01	94.28	3.310	2.7390
6.63	20.829	34.524	1.7357	414.28	117.37	94.85	3.315	2.7473
6.64	20.860	34.628	1.7383	415.53	117.72	95.42	3.320	2.7556
6.65	20.892	34.732	1.7410	416.79	118.08	96.00	3.325	2.7639
6.66	20.923	34.837	1.7436	418.04	118.43	96.58	3.330	2.7722
6.67	20.954	34.942	1.7462	419.30	118.79	97.16	3.335	2.7806
6.68	20.986	35.046	1.7488	420.56	119.14	97.74	3.340	2.7889
6.69	21.017	35.151	1.7514	421.82	119.50	98.33	3.345	2.7973
6.70	21.049	35.257	1.7541	423.08	119.86	98.92	3.350	2.8056
6.71	21.080	35.362	1.7567	424.34	120.22	99.51	3.355	2.8140
6.72	21.112	35.467	1.7593	425.61	120.57	100.10	3.360	2.8224
6.73	21.143	35.573	1.7619	426.88	120.93	100.70	3.365	2.8308
6.74	21.174	35.679	1.7645	428.15	121.29	101.30	3.370	2.8392
6.75	21.206	35.785	1.7671	429.42	121.65	101.90	3.375	2.8477
6.76	21.237	35.891	1.7698	430.69	122.01	102.51	3.380	2.8561
6.77	21.269	35.997	1.7724	431.96	122.38	103.12	3.385	2.8646
6.78	21.300	36.103	1.7750	433.24	122.74	103.73	3.390	2.8730
6.79	21.331	36.210	1.7776	434.52	123.10	104.34	3.395	2.8815
6.80	21.363	36.317	1.7802	435.80	123.46	104.96	3.400	2.8900
6.81	21.394	36.424	1.7829	437.08	123.83	105.57	3.405	2.8985
6.82	21.426	36.531	1.7855	438.37	124.19	106.20	3.410	2.9070
6.83	21.457	36.638	1.7881	439.66	124.55	106.82	3.415	2.9156
6.84	21.488	36.745	1.7907	440.94	124.92	107.45	3.420	2.9241
6.85	21.520	36.853	1.7933	442.23	125.28	108.08	3.425	2.9327
6.86	21.551	36.961	1.7959	443.53	125.65	108.71	3.430	2.9412
6.87	21.583	37.068	1.7986	444.82	126.02	109.34	3.435	2.9498
6.88	21.614	37.176	1.8012	446.12	126.38	109.98	3.440	2.9584
6.89	21.646	37.284	1.8038	447.41	126.75	110.62	3.445	2.9670
6.90	21.677	37.393	1.8064	448.71	127.12	111.27	3.450	2.9756
6.91	21.708	37.501	1.8090	450.02	127.49	111.91	3.455	2.9843
6.92	21.740	37.610	1.8117	451.32	127.86	112.56	3.460	2.9929
6.93	21.771	37.719	1.8143	452.62	128.23	113.21	3.465	3.0016
6.94	21.803	37.828	1.8169	453.93	128.60	113.87	3.470	3.0102
6.95	21.834	37.937	1.8195	455.24	128.97	114.53	3.475	3.0189
6.96	21.865	38.046	1.8221	456.55	129.34	115.19	3.480	3.0276
6.97	21.897	38.155	1.8247	457.86	129.71	115.85	3.485	3.0363
6.98	21.928	38.265	1.8274	459.18	130.09	116.52	3.490	3.0450
6.99	21.960	38.375	1.8300	460.50	130.46	117.19	3.495	3.0538
7.00	21.991	38.485	1.8326	461.81	130.83	117.86	3.500	3.0625

Properties of Tubes and Round Bars (Continued) 7.00 inches – 7.50 inches

For Tubes use differences for A, W, I and V (for volume of wall only), sum for R^2, and direct tabular values for C, S, y and V (for capacity). For Round Bars use all tabular values direct.

Diam. in inches D	Circumference in inches C	Area cross section sq. in. A	Per foot length: Surface sq. ft. S	Per foot length: Volume cu. in. V	Per foot length: Weight, lbs. steel W	Moment of inertia I	Distance from axis to farthest fiber y	Radius of gyration squared R^2
7.00	21.991	38.485	1.8326	461.81	130.83	117.86	3.500	3.0625
7.01	22.023	38.595	1.8352	463.13	131.21	118.53	3.505	3.0713
7.02	22.054	38.705	1.8378	464.46	131.58	119.21	3.510	3.0800
7.03	22.085	38.815	1.8404	465.78	131.96	119.89	3.515	3.0888
7.04	22.117	38.926	1.8431	467.11	132.33	120.58	3.520	3.0976
7.05	22.148	39.036	1.8457	468.44	132.71	121.26	3.525	3.1064
7.06	22.180	39.147	1.8483	469.76	133.08	121.95	3.530	3.1152
7.07	22.211	39.258	1.8509	471.10	133.46	122.64	3.535	3.1241
7.08	22.242	39.369	1.8535	472.43	133.84	123.34	3.540	3.1329
7.09	22.274	39.480	1.8562	473.77	134.22	124.04	3.545	3.1418
7.10	22.305	39.592	1.8588	475.10	134.60	124.74	3.550	3.1506
7.11	22.337	39.704	1.8614	476.44	134.98	125.44	3.555	3.1595
7.12	22.368	39.815	1.8640	477.78	135.36	126.15	3.560	3.1684
7.13	22.400	39.927	1.8666	479.13	135.74	126.86	3.565	3.1773
7.14	22.431	40.039	1.8693	480.47	136.12	127.57	3.570	3 [illegible]
7.15	22.462	40.152	1.8719	481.82	136.50	128.29	3.575	3.1952
7.16	22.494	40.264	1.8745	483.17	136.88	129.01	3.580	3.2041
7.17	22.525	40.376	1.8771	484.52	137.26	129.73	3.585	3.2131
7.18	22.557	40.489	1.8797	485.87	137.65	130.46	3.590	3.2220
7.19	22.588	40.602	1.8823	487.22	138.03	131.19	3.595	3.2310
7.20	22.619	40.715	1.8850	488.58	138.41	131.92	3.600	3.2400
7.21	22.651	40.828	1.8876	489.94	138.80	132.65	3.605	3.2490
7.22	22.682	40.942	1.8902	491.30	139.18	133.39	3.610	3.2580
7.23	22.714	41.055	1.8928	492.66	139.57	134.13	3.615	3.2671
7.24	22.745	41.169	1.8954	494.02	139.96	134.87	3.620	3.2761
7.25	22.777	41.282	1.8980	495.39	140.34	135.62	3.625	3.2852
7.26	22.808	41.396	1.9007	496.76	140.73	136.37	3.630	3.2942
7.27	22.840	41.511	1.9033	498.13	141.12	137.12	3.635	3.3033
7.28	22.871	41.625	1.9059	499.50	141.51	137.88	3.640	3.3124
7.29	22.902	41.739	1.9085	500.87	141.90	138.64	3.645	3.3215
7.30	22.934	41.854	1.9111	502.25	142.29	139.40	3.650	3.3306
7.31	22.965	41.969	1.9138	503.62	142.68	140.17	3.655	3.3398
7.32	22.996	42.084	1.9164	505.00	143.07	140.93		3.3489
7.33	23.028	42.199	1.9190	506.38	143.46	141.71		3.3581
7.34	23.059	42.314	1.9216	507.77	143.85	142.48		3.3672
7.35	23.091	42.429	1.9242	509.15	144.24	143.26		3.3764
7.36	23.122	42.545	1.9268	510.54	144.63	144.04		3.3856
7.37	23.154	42.660	1.9295	511.92	145.03	144.82		3.3948
7.38	23.185	42.776	1.9321	513.31	145.42	145.61		3.4040
7.39	23.216	42.892	1.9347	514.71	145.82	146.40		3.4133
7.40	23.248	43.008	1.9373	516.10	146.21	147.20	3.700	3.4225
7.41	23.279	43.125	1.9399	517.50	146.61	147.99	3.705	3.4318
7.42	23.311	43.241	1.9426	518.89	147.00	148.79	3.710	3.4410
7.43	23.342	43.358	1.9452	520.29	147.40	149.60	3.715	3.4503
7.44	23.373	43.475	1.9478	521.70	147.80	150.40	3.720	3.4596
7.45	23.405	43.592	1.9504	523.10	148.19	151.22	3.725	3.4689
7.46	23.436	43.709	1.9530	524.50	148.59	152.03	3.730	3.4782
7.47	23.468	43.826	1.9556	525.91	148.99	152.85	3.735	3.4876
7.48	23.499	43.943	1.9583	527.32	149.39	153.67	3.740	3.4969
7.49	23.531	44.061	1.9609	528.73	149.79	154.49	3.745	3.5063
7.50	23.562	44.179	1.9635	530.14	150.19	155.32	3.750	3.5156

Properties of Tubes and Round Bars (Continued) 7.50 inches – 8.00 inches

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diameter in inches *D*	Circumference in inches *C*	Area cross section sq. in. *A*	Per foot length: Surface sq. ft. *S*	Per foot length: Volume cu. in. *V*	Per foot length: Weight, lbs. steel *W*	Moment of inertia *I*	Distance from axis to farthest fiber *y*	Radius of gyration squared R^2
7 50	23 562	44 179	1 9635	530 14	150 19	155 32	3 750	3 5156
7 51	23 593	44 297	1 9661	531 56	150 59	156 15	3 755	3 5250
7 52	23 625	44 415	1 9687	532 97	150 99	156 98	3 760	3 5344
7 53	23 656	44 533	1 9713	534 39	151 39	157 82	3 765	3 5438
7 54	23 688	44 651	1 9740	535 81	151 [illegible]	158 66	3 770	3 5532
7 55	23 719	44 770	1 9766	537 24	152 20	159 50	3 775	3 5627
7 56	23 750	44 888	1 9792	538 66	152 60	160 35	3 780	3 5721
7 57	23 782	45 007	1.9818	540 09	153 01	161 20	3 785	3 5816
7 58	23 813	45 126	1 9844	541 51	153.41	162 05	3 790	3 5910
7 59	23 845	45 245	1 9871	542 94	153.82	162 91	3 795	3 6005
7 60	23 876	45 365	1 9897	544 38	154 22	163 77	3 800	3 6100
7 61	23 908	45 484	1 9923	545 81	154 63	164 63	3 805	3 6195
7 62	23 939	45 604	1 9949	547 24	155.03	165 50	3 810	3 6290
7 63	23 970	45 723	1 9975	548 68	155 44	166 37	3 815	3 6386
7 64	24 002	45 843	2.0001	550 12	155 85	167 24	3 820	3 6481
7 65	24 033	45 963	[illegible]	551 56	156 [illegible]	168 12	3 825	3 6577
7 66	24 065	46 084	2 0054	553 00	156 67	169 00		3.6672
7 67	24 096	46 204	2 0080	554 45	157 [illegible]	169 88		3 6768
7 68	24 127	46 325	2 0106	555 90	157.49	170 77		3 6864
7 69	24 159	46 445	2 0132	557 34	157 90	171 66		3 6960
7 70	24 190	46 566	2 0159	558 80	158 31	172 56		3 7056
7 71	24 222	46 687	2 0185	560 25	158.72	173 46		3 7153
7 72	24 253	46 808	2 0211	561 70	159 13	174 36		3 7249
7 73	24 285	46.930	2 0237	563 16	159 54	175 26		3 7346
7 74	24 316	47 051	2 0263	564 62	159 96	176 17	3 870	3 7442
7 75	24 347	47 173	2 0289	566 08	160 37	177 08	3 875	3 7539
7 76	24 379	47 295	2 0316	567 54	160 78	178 00	3 880	3.7636
7 77	24 410	47 417	2 0342	569 00	161 20	178 92	3 885	3 7733
7 78	24 442	47 539	2 0368	570 47	161 61	179 84	3 890	3 7830
7 79	24 473	47 661	2 0394	571 93	162 03	180 77	3 895	3 7928
7 80	24 504	47.784	2 0420	573 40	162 45	181 70	3 900	3 8025
7 81	24 536	47 906	2 0447	574 87	162 [illegible]	182 63	3 905	3 8123
7 82	24 567	48 029	2 0473	576 35	163 28	183 57	3 910	3 8220
7 83	24 599	48 152	2 0499	577 82	163.70	184 51	3 915	3 8318
7 84	24 630	48 275	2 0525	579 30	164 12	185 45	3 920	3 8416
7 85	24 661	48 398	2 0551	580 78	164 53	186 40	3 925	3.8514
7 86	24 693	48 522	2 0577	582 26	164 95	187 35	3 930	3 8612
7.87	24 724	48.645	2.0604	583 74	165 37	188 31	3 935	3 8711
7 88	24 756	48 769	2 0630	585 23	165 79	189 27	3 940	3.8809
7 89	24 787	48.893	2 0656	586 71	166 22	190 23	3 945	3 8908
7 90	24 819	49 017	2 0682	588 20	166 64	191 20	3 950	3 9006
7 91	24 850	49 141	2 0708	589 69	167 06	192 17	3 955	3 9105
7 92	24 881	49 265	2 0735	591 18	167 48	193 14	3 960	3 9204
7 93	24 913	49 390	2 0761	592 68	167 91	194 12	3 965	3 9303
7 94	24 944	49 514	2 0787	594 17	168 33	195 10	3 970	3 9402
7 95	24 976	49 639	2 0813	595 67	168 75	196 09	3 975	3 9502
7 96	25 007	49 764	2 0839	597 17	169 18	197.07	3 980	3 9601
7 97	25 038	49 889	2 0865	598 67	169 60	198 [illegible]	3 985	3 9701
7 98	25 070	50 014	2 0892	600 17	170 03	199 06	3 990	3 9800
7 99	25 101	50 140	2 0918	601 68	170 46	200 06	3 995	3 9900
8.00	25 133	50 265	2 0944	603 19	170 88	201 06	4 000	4 0000

Properties of Tubes and Round Bars (Continued) 8.00 inches 8.50 inches

For Tubes use differences for A, W, I and V (for volume of wall only), sum for R^2, and direct tabular values for C, S, y and V (for capacity). For Round Bars use all tabular values direct.

Diam. in inches D	Circumference in inches C	Area cross section sq. in. A	Per foot length: Surface sq. ft. S	Per foot length: Volume cu. in. V	Per foot length: Weight, lbs. steel W	Moment of inertia I	Distance from axis to farthest fiber y	Radius of gyration squared R^2
8.00	25.133	50.265	2.0944	603.19	170.88	201.06	4.000	4.0000
8.01	25.164	50.391	2.0970	604.69	171.31	202.07	4.005	4.0100
8.02	25.196	50.517	2.0996	606.21	171.74	203.08	4.010	4.0200
8.03	25.227	50.643	2.1022	607.72	172.17	204.10	4.015	4.0301
8.04	25.258	50.769	2.1049	609.23	172.60	205.11	4.020	4.0401
8.05	25.290	50.896	2.1075	610.75	173.03	206.14	4.025	4.0502
8.06	25.321	51.022	2.1101	612.27	173.46	207.16	4.030	4.0602
8.07	25.353	51.149	2.1127	613.79	173.89	208.19	4.035	4.0703
8.08	25.384	51.276	2.1153	615.31	174.32	209.23	4.040	4.0804
8.09	25.415	51.403	2.1180	616.83	174.75	210.26	4.045	4.0905
8.10	25.447	51.530	2.1206	618.36	175.18	211.31	4.050	4.1006
8.11	25.478	51.657	2.1232	619.89	175.61	212.35	4.055	4.1108
8.12	25.510	51.785	2.1258	621.42	176.05	213.40	4.060	4.1209
8.13	25.541	51.912	2.1284	622.95	176.48	214.45	4.065	4.1311
8.14	25.573	52.040	2.1310	624.48	176.92	215.51	4.070	4.1412
8.15	25.604	52.168	2.1337	626.02	177.35	216.57	4.075	4.1514
8.16	25.635	52.296	2.1363	627.55	177.79	217.64	4.080	4.1616
8.17	25.667	52.424	2.1389	629.09	178.22	218.71	4.085	4.1718
8.18	25.698	52.553	2.1415	630.63	178.66	219.78	4.090	4.1820
8.19	25.730	52.681	2.1441	632.18	179.10	220.85	4.095	4.1923
8.20	25.761	52.810	2.1468	633.72	179 53	221.93	4.100	4.2025
8.21	25.792	52.939	2.1494	635.27	179.97	223.02	4.105	4.2128
8.22	25.824	53.068	2.1520	636.82	180.41	224.11	4.110	4.2230
8.23	25.855	53.197	2.1546	638.37	180.85	225.20	4.115	4.2333
8.24	25.887	53.327	2.1572	639.92	181.29	226.30	4.120	4.2436
8.25	25.918	53.456	2.1598	641.47	181.73	227.40	4.125	4.2539
8.26	25.950	53.586	2.1625	643.03	182.17	228.50	4.130	4.2642
8.27	25.981	53.716	2.1651	644.59	182.61	229.61	4.135	4.2746
8.28	26.012	53.846	2.1677	646.15	183.05	230.72	4.140	4.2849
8.29	26.044	53.976	2.1703	647.71	183.50	231.84	4.145	4.2953
8.30	26.075	54.106	2.1729	649.27	183.94	232.96	4.150	4.3056
8.31	26.107	54.237	2.1756	650.84	184.38	234.09	4.155	4.3160
8.32	26.138	54.367	2.1782	652.41	184.83	235.21	4.160	4.3264
8.33	26.169	54.498	2.1808	653.97	185.27	236.35	4.165	4.3368
8.34	26.201	54.629	2.1834	655.55	185.72	237.48	4.170	4.3472
8.35	26.232	54.760	2.1860	657.12	186.16	238.63	4.175	4.3577
8.36	26.264	54.891	2.1886	658.69	186.61	239.77	4.180	4.3681
8.37	26.295	55.023	2.1913	660.27	187.05	240.92	4.185	4.3786
8.38	26.327	55.154	2.1939	661.85	187.50	242.07	4.190	4.3890
8.39	26.358	55.286	2.1965	663.43	187.95	243.23	4.195	4.3995
8.40	26.389	55.418	2.1991	665.01	188.40	244.39	4.200	4.4100
8.41	26.421	55.550	2.2017	666.60	188.85	245.56	4.205	4.4205
8.42	26.452	55.682	2.2044	668.18	189.30	246.73	4.210	4.4310
8.43	26.484	55.814	2.2070	669.77	189.75	247.90	4.215	4.4416
8.44	26.515	55.947	2.2096	671.36	190.20	249.08	4.220	4.4521
8.45	26.546	56.079	2.2122	672.95	190.65	250.26	4.225	4.4627
8.46	26.578	56.212	2.2148	674.55	191.10	251.45	4.230	4.4732
8.47	26.609	56.345	2.2174	676.14	191.55	252.64	4.235	4.4838
8.48	26.641	56.478	2.2201	677.74	192.00	253.84	4.240	4.4944
8.49	26.672	56.612	2.2227	679.34	192.46	255.04	4.245	4.5050
8.50	26.704	56.745	2.2253	680.94	192.91	256.24	4.250	4.5156

Properties of Tubes and Round Bars (Continued) **8.50** inches **9.00** inches

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches *D*	Circumference in inches *C*	Area cross section sq. in. *A*	Per foot length: Surface sq. ft. *S*	Per foot length: Volume cu. in. *V*	Per foot length: Weight, lbs. steel *W*	Moment of inertia *I*	Distance from axis to farthest fiber *y*	Radius of gyration squared R^2
8.50	26.704	56.745	2.2253	680.94	192.91	256.24	4.250	4.5156
8.51	26.735	56.879	2.2279	682.54	193.36	257.45	4.255	4.5263
8.52	26.766	57.012	2.2305	684.15	193.82	258.66	4.260	4.5369
8.53	26.798	57.146	2.2331	685.76	194.27	259.88	4.265	4.5476
8.54	26.829	57.280	2.2358	687.36	194.73	261.10	4.270	4.5582
8.55	26.861	57.415	2.2384	688.97	195.19	262.32	4.275	4.5689
8.56	26.892	57.549	2.2410	690.59	195.64	263.55	4.280	4.5796
8.57	26.923	57.683	2.2436	692.20	196.10	264.79	4.285	4.5903
8.58	26.955	57.818	2.2462	693.82	196.56	266.02	4.290	4.6010
8.59	26.986	57.953	2.2489	695.44	197.02	267.27	4.295	4.6118
8.60	27.018	58.088	2.2515	697.06	197.48	268.51	4.300	4.6225
8.61	27.049	58.223	2.2541	698.68	197.94	269.76	4.305	4.6333
8.62	27.081	58.359	2.2567	700.30	198.40	271.02	4.310	4.6440
8.63	27.112	58.494	2.2593	701.93	198.86	272.28	4.315	4.6548
8.64	27.143	58.630	2.2619	703.56	199.32	273.54	4.320	4.6656
8.65	27.175	58.765	2.2646	705.19	199.78	274.81	4.325	4.6764
8.66	27.206	58.901	2.2672	706.82	200.24	276.08	4.330	4.6872
8.67	27.238	59.038	2.2698	708.45	200.70	277.36	4.335	4.6981
8.68	27.269	59.174	2.2724	710.09	201.17	278.64	4.340	4.7089
8.69	27.300	59.310	2.2750	711.72	201.63	279.93	4.345	4.7198
8.70	27.332	59.447	2.2777	713.36	202.10	281.22	4.350	4.7306
8.71	27.363	59.584	2.2803	715.00	202.56	282.52	4.355	4.7415
8.72	27 395	59.720	2.2829	716.65	203.03	283.82	4.360	4.7524
8.73	27.426	59.857	2.2855	718.29	203.49	285.12	4.365	4.7633
8.74	27.458	59.995	2.2881	719.94	203.96	286.43	4.370	4.7742
8.75	27.489	60.132	2.2907	721.58	204.42	287.74	4.375	4.7852
8.76	27.520	60.270	2.2934	723.23	204.89	289.06	4.380	4.7961
8.77	27.552	60.407	2.2960	724.89	205.36	290.38	4.385	4.8071
8.78	27.583	60.545	2.2986	726.54	205.83	291.71	4.390	4.8180
8.79	27.615	60.683	2.3012	728.20	206.30	293.04	4.395	4.8290
8.80	27.646	60.821	2.3038	729.85	206.77	294.37	4.400	4.8400
8.81	27.677	60.960	2.3065	731.51	207.24	295.72	4.405	4.8510
8.82	27.709	61.098	2.3091	733.18	207.71	297.06	4.410	4.8620
8.83	27.740	61.237	2.3117	734.84	208.18	298.41	4.415	4.8731
8.84	27.772	61.375	2.3143	736.50	208.65	299.76	4.420	4.8841
8.85	27.803	61.514	2.3169	738.17	209.12	301.12	4.425	4.8952
8.86	27.835	61.653	2.3195	739.84	209.60	302.49	4.430	4.9062
8.87	27.866	61.793	2.3222	741.51	210.07	303.85	4.435	4.9173
8.88	27.897	61.932	2.3248	743.19	210.54	305.23	4.440	4.9284
8.89	27.929	62.072	2.3274	744.86	211.02	306.60	4.445	4.9395
8.90	27.960	62.211	2.3300	746.54	211.49	307.99	4.450	4.9506
8.91	27.992	62.351	2.3326	748.22	211.97	309.37	4.455	4.9618
8.92	28.023	62.491	2.3353	749.90	212.45	310.76	4.460	4.9729
8.93	28.054	62.631	2.3379	751.58	212.92	312.16	4.465	4.9841
8.94	28.086	62.772	2.3405	753.26	213.40	313.56	4.470	4.9952
8.95	28.117	62.912	2.3431	754.95	213.88	314.97	4.475	5.0064
8.96	28.149	63.053	2.3457	756.64	214.36	316.37	4.480	5.0176
8.97	28.180	63.194	2.3483	758.33	214.83	317.79	4.485	5.0288
8.98	28.212	63.335	2 3510	760.02	215.31	319.21	4.490	5 0400
8.99	28.243	63.476	2.3536	761.71	215.79	320 63	4.495	5.0513
9.00	28.274	63.617	2.3562	763.41	216.27	322.06	4.500	5.0625

Properties of Tubes and Round Bars (Continued) 9.00 inches / 9.50 inches

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). *For Round Bars* use all tabular values direct.

Diam. in inches D	Circumference in inches C	Area cross section sq. in. A	Per foot length: Surface sq. ft. S	Per foot length: Volume cu. in. V	Per foot length: Weight, lbs. steel W	Moment of inertia I	Distance from axis to farthest fiber y	Radius of gyration squared R^2
9.00	28.274	63.617	2.3562	763.41	216.27	322.06	4.500	5.0625
9.01	28.306	63.759	2.3588	765.10	216.75	323.50	4.505	5.0738
9.02	28.337	63.900	2.3614	766.80	217.24	324.93	4.510	5.0850
9.03	28.369	64.042	2.3640	768.50	217.72	326.38	4.515	5.0963
9.04	28.400	64.184	2.3667	770.21	218.20	327.83	4.520	5.1076
9.05	28.431	64.326	2.3693	771.91	218.68	329.28	4.525	5.1189
9.06	28.463	64.468	2.3719	773.62	219.17	330.74	4.530	5.1302
9.07	28.494	64.611	2.3745	775.33	219.65	332.20	4.535	5.1416
9.08	28.526	64.753	2.3771	777.04	220.14	333.67	4.540	5.1529
9.09	28.557	64.896	2.3798	778.75	220.62	335.14	4.545	5.1643
9.10	28.588	65.039	2.3824	780.47	221.11	336.62	4.550	5.1756
9.11	28.620	65.182	2.3850	782.18	221.59	338.10	4.555	5.1870
9.12	28.651	65.325	2.3876	783.90	222.08	339.59	4.560	5.1984
9.13	28.683	65.468	2.3902	785.62	222.57	341.08	4.565	5.2098
9.14	28.714	65.612	2.3928	787.34	223.05	342.57	4.570	5.2212
9.15	28.746	65.755	2.3955	789.07	223.54	344.08	4.575	5.2327
9.16	28.777	65.899	2.3981	790.79	224.03	345.58	4.580	5.2441
9.17	28.808	66.043	2.4007	792.52	224.52	347.09	4.585	5.2556
9.18	28.840	66.187	2.4033	794.25	225.01	348.61	4.590	5.2670
9.19	28.871	66.332	2.4059	795.98	225.50	350.13	4.595	5.2785
9.20	28.903	66.476	2.4086	797.71	225.99	351.66	4.600	5.2900
9.21	28.934	66.621	2.4112	799.45	226.48	353.19	4.605	5.3015
9.22	28.965	66.765	2.4138	801.19	226.98	354.73	4.610	5.3130
9.23	28.997	66.910	2.4164	802.92	227.47	356.27	4.615	5.3246
9.24	29.028	67.055	2.4190	804.66	227.96	357.81	4.620	5.3361
9.25	29.060	67.201	2.4216	806.41	228.46	359.37	4.625	5.3477
9.26	29.091	67.346	2.4243	808.15	228.95	360.92	4.630	5.3592
9.27	29.123	67.492	2.4269	809.90	229.44	362.48	4.635	5.3708
9.28	29.154	67.637	2.4295	811.65	229.94	364.05	4.640	5.3824
9.29	29.185	67.783	2.4321	813.40	230.44	365.62	4.645	5.3940
9.30	29.217	67.929	2.4347	815.15	230.93	367.20	4.650	5.4056
9.31	29.248	68.075	2.4374	816.90	231.43	368.78	4.655	5.4173
9.32	29.280	68.222	2.4400	818.66	231.93	370.37		5.4289
9.33	29.311	68.368	2.4426	820.42	232.42	371.96		5.4406
9.34	29.342	68.515	2.4452	822.18	232.92	373.56		5.4522
9.35	29.374	68.661	2.4478	823.94	233.42	375.16		5.4639
9.36	29.405	68.808	2.4504	825.70	233.92	376.77		5.4756
9.37	29.437	68.956	2.4531	827.47	234.42	378.38		5.4873
9.38	29.468	69.103	2.4557	829.23	234.92	380.00		5.4990
9.39	29.500	69.250	2.4583	831.00	235.42	381.62		5.5108
9.40	29.531	69.398	2.4609	832.77	235.92	383.25	4.700	5.5225
9.41	29.562	69.546	2.4635	834.55	236.43	384.88	4.705	5.5343
9.42	29.594	69.693	2.4662	836.32	236.93	386.52	4.710	5.5460
9.43	29.625	69.841	2.4688	838.10	237.43	388.17	4.715	5.5578
9.44	29.657	69.990	2.4714	839.88	237.94	389.81	4.720	5.5696
9.45	29.688	70.138	2.4740	841.66	238.44	391.47	4.725	5.5814
9.46	29.719	70.287	2.4766	843.44	238.95	393.13	4.730	5.5932
9.47	29.751	70.435	2.4792	845.22	239.45	394.79	4.735	5.6051
9.48	29.782	70.584	2.4819	847.01	239.96	396.46	4.740	5.6169
9.49	29.814	70.733	2.4845	848.80	240.46	398.14	4.745	5.6288
9.50	29.845	70.882	2.4871	850.59	240.97	399.82	4.750	5.6406

Properties of Tubes and Round Bars (Continued) 9.50 inches / 10.00 inches

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches *D*	Circumference in inches *C*	Area cross section sq. in. *A*	Per foot length: Surface sq. ft. *S*	Per foot length: Volume cu. in. *V*	Per foot length: Weight, lbs steel *W*	Moment of inertia *I*	Distance from axis to farthest fiber *y*	Radius of gyration squared R^2
9.50	29.845	70.882	2.4871	850.59	240.97	399.82	4.750	5.6406
9.51	29.877	71.031	2.4897	852.38	241.48	401.51	4.755	5.6525
9.52	29.908	71.181	2.4923	854.17	241.99	403.20	4.760	5.6644
9.53	29.939	71.330	2.4949	855.97	242.50	404.89	4.765	5.6763
9.54	29.971	71.480	2.4976	857.76	243.00	406.60	4.770	5.6882
9.55	30.002	71.630	2.5002	859.56	243.51	408.30	4.775	5.7002
9.56	30.034	71.780	2.5028	861.36	244.02	410.02	4.780	5.7121
9.57	30.065	71.931	2.5054	863.17	244.54	411.74	4.785	5.7241
9.58	30.096	72.081	2.5080	864.97	245.05	413.46	4.790	5.7360
9.59	30.128	72.232	2.5107	866.78	245.56	415.19	4.795	5.7480
9.60	30.159	72.382	2.5133	868.59	246.07	416.92	4.800	5.7600
9.61	30.191	72.533	2.5159	870.40	246.58	418.66	4.805	5.7720
9.62	30.222	72.685	2.5185	872.21	247.10	420.41	4.810	5.7840
9.63	30.254	72.836	2.5211	874.02	247.61	422.16	4.815	5.7961
9.64	30.285	72.988	2.5237	875.84	248.13	423.91	4.820	5.8081
9.65	30.316	73.139	2.5264	877.66	248.64	425.68	4.825	5.8202
9.66	30.348	73.291	2.5290	879.48	249.16	427.44	4.830	5.8322
9.67	30.379	73.443	2.5316	881.30	249.67	429.22	4.835	5.8443
9.68	30.411	73.596	2.5342	883.12	250.19	430.99	4.840	5.8564
9.69	30.442	73.748	2.5368	884.95	250.71	432.78	4.845	5.8685
9.70	30.473	73.898	2.5395	886.78	251.22	434.57		5.8806
9.71	30.505	74.051	2.5421	888.61	251.74	436.36		5.8928
9.72	30.536	74.203	2.5447	890.44	252.26	438.16		5.9049
9.73	30.568	74.356	2.5473	892.27	252.78	439.97		5.9171
9.74	30.599	74.509	2.5499	894.11	253.30	441.78	4.870	5.9292
9.75	30.631	74.662	2.5525	895.94	253.82	443.60	4.875	5.9414
9.76	30.662	74.815	2.5552	897.78	254.34	445.42	4.880	5.9536
9.77	30.693	74.969	2.5578	899.62	254.86	447.25	4.885	5.9658
9.78	30.725	75.122	2.5604	901.46	255.38	449.08	4.890	5.9780
9.79	30.756	75.276	2.5630	903.31	255.91	450.92	4.895	5.9903
9.80	30.788	75.430	2.5656	905.16	256.43	452.77	4.900	6.0025
9.81	30.819	75.584	2.5683	907.00	256.95	454.62	4.905	6.0148
9.82	30.850	75.738	2.5709	908.85	257.48	456.47	4.910	6.0270
9.83	30.882	75.892	2.5735	910.71	258.00	458.34	4.915	6.0393
9.84	30.913	76.047	2.5761	912.56	258.53	460.20	4.920	6.0516
9.85	30.945	76.201	2.5787	914.42	259.05	462.08	4.925	6.0639
9.86	30.976	76.356	2.5813	916.27	259.58	463.96	4.930	6.0762
9.87	31.008	76.511	2.5840	918.13	260.11	465.84	4.935	6.0886
9.88	31.039	76.666	2.5866	919.99	260.63	467.73	4.940	6.1009
9.89	31.070	76.821	2.5892	921.86	261.16	469.63	4.945	6.1133
9.90	31.102	76.977	2.5918	923.72	261.69	471.53	4.950	6.1256
9.91	31.133	77.132	2.5944	925.59	262.22	473.44	4.955	6.1380
9.92	31.165	77.288	2.5970	927.46	262.75	475.35	4.960	6.1504
9.93	31.196	77.444	2.5997	929.33	263.28	477.27	4.965	6.1628
9.94	31.227	77.600	2.6023	931.20	263.81	479.20	4.970	6.1752
9.95	31.259	77.756	2.6049	933.08	264.34	481.13	4.975	6.1877
9.96	31.290	77.913	2.6075	934.95	264.87	483.07	4.980	6.2001
9.97	31.322	78.069	2.6101	936.83	265.40	485.01	4.985	6.2126
9.98	31.353	78.226	2.6128	938.71	265.94	486.96	4.990	6.2250
9.99	31.385	78.383	2.6154	940.59	266.47	488.91	4.995	6.2375
10.00	31.416	78.540	2.6180	942.48	267.00	490.87	5.000	6.2500

Properties of Tubes and Round Bars (Continued) **10.00** inches
10.50 inches

For Tubes use differences for A, W, I and V (for volume of wall only), sum for R^2, and direct tabular values for C, S, y and V (for capacity). For Round Bars use all tabular values direct.

Diam. in inches D	Circumference in inches C	Area cross section sq. in. A	Per foot length: Surface sq. ft. S	Per foot length: Volume cu. in. V	Per foot length: Weight, lbs. steel W	Moment of inertia I	Distance from axis to farthest fiber y	Radius of gyration squared R^2
10.00	31.416	78.540	2.6180	942.48	267.00	490.87	5.000	6.2500
10.01	31.447	78.697	2.6206	944.36	267.54	492.84	5.005	6.2625
10.02	31.479	78.854	2.6232	946.25	268.07	494.81	5.010	6.2750
10.03	31.510	79.012	2.6258	948.14	268.61	496.79	5.015	6.2876
10.04	31.542	79.169	2.6285	950.03	269.14	498.78	5.020	6.3001
10.05	31.573	79.327	2.6311	951.93	269.68	500.77	5.025	6.3127
10.06	31.604	79.485	2.6337	953.82	270.22	502.76	5.030	6.3252
10.07	31.636	79.643	2.6363	955.72	270.76	504.76	5.035	6.3378
10.08	31.667	79.801	2.6389	957.62	271.29	506.8	5.040	6.3504
10.09	31.699	79.960	2.6416	959.52	271.83	508.8	5.045	6.3630
10.10	31.730	80.118	2.6442	961.42	272.37	510.8	5.050	6.3756
10.11	31.762	80.277	2.6468	963.33	272.91	512.8	5.055	6.3883
10.12	31.793	80.436	2.6494	965.23	273.45	514.9	5.060	6.4009
10.13	31.824	80.595	2.6520	967.14	273.99	516.9	5.065	6.4136
10.14	31.856	80.754	2.6546	969.05	274.53	518.9	5.070	6.42[illegible]
10.15	31.887	80.914	2.6573	970.96	275.07	521.0	5.075	6.4389
10.16	31.919	81.073	2.6599	972.88	275.62	523.1	5.080	6.4516
10.17	31.950	81.233	2.6625	974.79	276.16	525.1	5.085	6.4643
10.18	31.981	81.393	2.6651	976.71	276.70	527.2	5.090	6.4770
10.19	32.013	81.553	2.6677	978.63	277.25	529.3	5.095	6.4898
10.20	32.044	81.713	2.6704	980.55	277.79	531.3	5.100	6.5025
10.21	32.076	81.873	2.6730	982.48	278.34	533.4	5.105	6.5153
10.22	32.107	82.034	2.6756	984.40	278.88	535.5	5.110	6.5280
10.23	32.138	82.194	2.6782	986.33	279.43	537.6	5.115	6.5408
10.24	32.170	82.355	2.6808	988.26	279.97	539.7	5.120	6.5536
10.25	32.201	82.516	2.6834	990.19	280.52	541.8	5.125	6.5664
10.26	32.233	82.677	2.6861	992.12	281.07	544.0	5.130	6.5792
10.27	32.264	82.838	2.6887	994.06	281.62	546.1	5.135	6.5921
10.28	32.296	83.000	2.6913	996.00	282.17	548.2	5.140	6.6049
10.29	32.327	83.161	2.6939	997.93	282.71	550.3	5.145	6.6178
10.30	32.358	83.323	2.6965	999.87	283.26	552.5	5.150	6.6306
10.31	32.390	83.485	2.6992	1001.82	283.81	554.6	5.155	6.6435
10.32	32.421	83 647	2.7018	1003.76	284.37	556.8	5.160	6.6564
10.33	32.453	83.809	2.7044	1005.71	284.92	558.9	5.165	6.6693
10.34	32.484	83.971	2.7070	1007.66	285.47	561.1	5.170	6.6822
10.35	32.515	84.134	2.7096	1009.61	286.02	563.3	5.175	6.6952
10.36	32.547	84.296	2.7122	1011.56	286.57	565.5	5.180	6.7081
10.37	32.578	84.459	2.7149	1013.51	287.13	567.7	5.185	6.7211
10.38	32.610	84.622	2.7175	1015.47	287.68	569.8	5.190	6.7340
10.39	32.641	84.785	2.7201	1017.42	288.24	572.0	5.195	6.7470
10.40	32.673	84.949	2.7227	1019.38	288.79	574.3	5.200	6.7600
10.41	32.704	85.112	2.7253	1021.35	289.35	576.5	5.205	6.7730
10.42	32.735	85.276	2.7279	1023.31	289.90	578.7	5.210	6.7860
10.43	32.767	85.439	2.7306	1025.27	290.46	580.9	5.215	6.7991
10.44	32.798	85.603	2.7332	1027.24	291.02	583.1	5.220	6.8121
10.45	32.830	85.767	2.7358	1029.21	291.57	585.4	5.225	6.8252
10.46	32.861	85.932	2.7384	1031.18	292.13	587.6	5.230	6.8382
10.47	32.892	86.096	2.7410	1033.15	292.69	589.9	5.235	6.8513
10.48	32.924	86.261	2.7437	1035.13	293.25	592.1	5.240	6.8644
10.49	32.955	86.425	2.7463	1037.10	293.81	594.4	5.245	6.8775
10.50	32.987	86.590	2.7489	1039.08	294.37	596.7	5.250	6.8906

Properties of Tubes and Round Bars (Continued) 10.50 inches / 11.00 inches

For Tubes use differences for A, W, I and V (for volume of wall only), sum for R^2, and direct tabular values for C, S, y and V (for capacity). For Round Bars use all tabular values direct.

Diam. in inches D	Circumference in inches C	Area cross section sq. in. A	Per foot length: Surface sq. ft. S	Per foot length: Volume cu. in. V	Per foot length: Weight, lbs. steel W	Moment of inertia I	Distance from axis to farthest fiber y	Radius of gyration squared R^2
10.50	32.987	86.590	2.7489	1039.08	294.37	596.7	5.250	6.8906
10.51	33.018	86.755	2.7515	1041.06	294.93	598.9	5.255	6.9038
10.52	33.050	86.920	2.7541	1043.04	295.49	601.2	5.260	6.9169
10.53	33.081	87.086	2.7567	1045.03	296.06	603.5	5.265	6.9301
10.54	33.112	87.251	2.7594	1047.01	296.62	605.8	5.270	6.9432
10.55	33.144	87.417	2.7620	1049.00	297.18	608.1	5.275	6.9564
10.56	33.175	87.583	2.7646	1050.99	297.75	610.4	5.280	6.9696
10.57	33.207	87.749	2.7672	1052.98	298.31	612.7	5.285	6.9828
10.58	33.238	87.915	2.7698	1054.98	298.87	615.1	5.290	6.9960
10.59	33.269	88.081	2.7725	1056.97	299.44	617.4	5.295	7.0093
10.60	33.301	88.247	2.7751	1058.97	300.01	619.7	5.300	7.0225
10.61	33.332	88.414	2.7777	1060.97	300.57	622.1	5.305	7.0358
10.62	33.364	88.581	2.7803	1063.0	301.14	624.4	5.310	7.0490
10.63	33.395	88.748	2.7829	1065.0	301.71	626.8	5.315	7.0623
10.64	33.427	88.915	2.7855	1067.0	302.27	629.1	5.320	7.0756
10.65	33.458	89.082	2.7882	1069.0	302.84	631.5	5.325	7.0889
10.66	33.489	89.249	2.7908	1071.0	303.41	633.9	5.330	7.1022
10.67	33.521	89.417	2.7934	1073.0	303.98	636.2	5.335	7.1156
10.68	33.552	89.584	2.7960	1075.0	304.55	638.6	5.340	7.1289
10.69	33.584	89.752	2.7986	1077.0	305.12	641.0	5.345	7.1423
10.70	33.615	89.920	2.8013	1079.0	305.69	643.4	5.350	7.1556
10.71	33.646	90.088	2.8039	1081.1	306.26	645.8	5.355	7.1690
10.72	33.678	90.257	2.8065	1083.1	306.84	648.3	5.360	7.1824
10.73	33.709	90.425	2.8091	1085.1	307.41	650.7	5.365	7.1958
10.74	33.741	90.594	2.8117	1087.1	307.98	653.1	5.370	7.2092
10.75	33.772	90.763	2.8143	1089.2	308.56	655.5	5.375	7.2227
10.76	33.804	90.932	2.8170	1091.2	309.13	658.0	5.380	7.2361
10.77	33.835	91.101	2.8196	1093.2	309.71	660.4	5.385	7.2496
10.78	33.866	91.270	2.8222	1095.2	310.28	662.9	5.390	7.2630
10.79	33.898	91.439	2.8248	1097.3	310.86	665.4	5.395	7.2765
10.80	33.929	91.609	2.8274	1099.3	311.43	667.8	5.400	7.2900
10.81	33.961	91.779	2.8301	1101.3	312.01	670.3	5.405	7.3035
10.82	33.992	91.948	2.8327	1103.4	312.59	8	5.410	7.3170
10.83	34.023	92.118	2.8353	1105.4	313.17	3	5.415	7.3306
10.84	34.055	92.289	2.8379	1107.5	313.74	8	5.420	7.3441
10.85	34.086	92.459	2.8405	1109.5	314.32	3	5.425	7.3577
10.86	34.118	92.630	2.8431	1111.6	314.90	8	5.430	7.3712
10.87	34.149	92.800	2.8458	1113.6	315.48	3	5.435	7.3848
10.88	34.181	92.971	2.8484	1115.7	316.06	8	5.440	7.3984
10.89	34.212	93.142	2.8510	1117.7	316.65	4	5.445	7.4120
10.90	34.243	93.313	2.8536	1119.8	317.23	692.9	5.450	7.4256
10.91	34.275	93.484	2.8562	1121.8	317.81	695.5	5.455	7.4393
10.92	34.306	93.656	2.8589	1123.9	318.39	698.0	5.460	7.4529
10.93	34.338	93.827	2.8615	1125.9	318.98	700.6	5.465	7.4666
10.94	34.369	93.999	2.8641	1128.0	319.56	703.1	5.470	7.4802
10.95	34.400	94.171	2.8667	1130.1	320.14	705.7	5.475	7.4939
10.96	34.432	94.343	2.8693	1132.1	320.73	708.3	5.480	7.5076
10.97	34.463	94.516	2.8719	1134.2	321.31	710.9	5.485	7.5213
10.98	34.495	94.688	2.8746	1136.3	321.90	713.5	5.490	7.5350
10.99	34.526	94.860	2.8772	1138.3	322.49	716.1	5.495	7.5488
11.00	34.558	95.033	2.8798	1140.4	323.07	718.7	5.500	7.5625

Properties of Tubes and Round Bars (Continued) **11.00** inches **11.50** inches

For Tubes use differences for A, W, I and V (for volume of wall only), sum for R^2, and direct tabular values for C, S, y and V (for capacity). For Round Bars use all tabular values direct.

Diam. in inches D	Circumference in inches C	Area cross section sq. in. A	Per foot length: Surface sq. ft. S	Per foot length: Volume cu. in. V	Per foot length: Weight, lbs. steel W	Moment of inertia I	Distance from axis to farthest fiber y	Radius of gyration squared R^2
11.00	34.558	95.033	2.8798	1140.4	323.07	718.7	5.500	7.5625
11.01	34.589	95.206	2.8824	1142.5	323.66	721.3	5.505	7.5763
11.02	34.620	95.379	2.8850	1144.5	324.25	723.9	5.510	7.5900
11.03	34.652	95.552	2.8876	1146.6	324.84	726.6	5.515	7.6038
11.04	34.683	95.726	2.8903	1148.7	325.43	729.2	5.520	7.6176
11.05	34.715	95.899	2.8929	1150.8	326.02	731.8	5.525	7.6314
11.06	34.746	96.073	2.8955	1152.9	326.61	734.5	5.530	7.6452
11.07	34.777	96.247	2.8981	1155.0	327.20	737.2	5.535	7.6591
11.08	34.809	96.421	2.9007	1157.0	327.79	739.8	5.540	7.6729
11.09	34.840	96.595	2.9034	1159.1	328.38	742.5	5.545	7.6868
11.10	34.872	96.769	2.9060	1161.2	328.98	745.2	5.550	7.7006
11.11	34.903	96.943	2.9086	1163.3	329.57	747.9	5.555	7.7145
11.12	34.935	97.118	2.9112	1165.4	330.16	750.6	5.560	7.7284
11.13	34.966	97.293	2.9138	1167.5	330.76	753.3	5.565	7.7423
11.14	34.997	97.468	2.9164	1169.6	331.35	756.0	5.570	7.7562
11.15	35.029	97.643	2.9191	1171.7	331.95	758.7	5.575	7.7702
11.16	35.060	97.818	2.9217	1173.8	332.54	761.4	5.580	7.7841
11.17	35.092	97.993	2.9243	1175.9	333.14	764.2	5.585	7.7981
11.18	35.123	98.169	2.9269	1178.0	333.73	766.9	5.590	7.8120
11.19	35.154	98.344	2.9295	1180.1	334.33	769.6	5.595	7.8260
11.20	35.186	98.520	2.9322	1182.2	334.93	772.4	5.600	7.8400
11.21	35.217	98.696	2.9348	1184.4	335.53	775.2	5.605	7.8540
11.22	35.249	98.873	2.9374	1186.5	336.13	777.9	5.610	7.8680
11.23	35.280	99.049	2.9400	1188.6	336.73	780.7	5.615	7.8821
11.24	35.312	99.225	2.9426	1190.7	337.33	783.5	5.620	7.8961
11.25	35.343	99.402	2.9452	1192.8	337.93	786.3	5.625	7.9102
11.26	35.374	99.579	2.9479	1194.9	338.53	789.1	5.630	7.9242
11.27	35.406	99.756	2.9505	1197.1	339.13	791.9	5.635	7.9383
11.28	35.437	99.933	2.9531	1199.2	339.73	794.7	5.640	7.9524
11.29	35.469	100.110	2.9557	1201.3	340.33	797.5	5.645	7.9665
11.30	35.500	100.287	2.9583	1203.4	340.94	800.4	5.650	7.9806
11.31	35.531	100.465	2.9610	1205.6	341.54	803.2	5.655	7.9948
11.32	35.563	100.643	2.9636	1207.7	342.15	806.0	5.660	8.0089
11.33	35.594	100.821	2.9662	1209.8	342.75	808.9	5.665	8.0231
11.34	35.626	100.999	2.9688	1212.0	343.36	811.8	5.670	8.0372
11.35	35.657	101.177	2.9714	1214.1	343.96	814.6	5.675	8.0514
11.36	35.688	101.355	2.9740	1216.3	344.57	817.5	5.680	8.0656
11.37	35.720	101.534	2.9767	1218.4	345.17	820.4	5.685	8.0798
11.38	35.751	101.713	2.9793	1220.6	345.78	823.3	5.690	8.0940
11.39	35.783	101.891	2.9819	1222.7	346.39	826.2	5.695	8.1083
11.40	35.814	102.070	2.9845	1224.8	347.00	829.1	5.700	8.1225
11.41	35.846	102.249	2.9871	1227.0	347.61	832.0	5.705	8.1368
11.42	35.877	102.429	2.9897	1229.1	348.22	834.9	5.710	8.1510
11.43	35.908	102.608	2.9924	1231.3	348.83	837.8	5.715	8.1653
11.44	35.940	102.788	2.9950	1233.5	349.44	840.8	5.720	8.1796
11.45	35.971	102.968	2.9976	1235.6	350.05	843.7	5.725	8.1939
11.46	36.003	103.148	3.0002	1237.8	350.66	846.7	5.730	8.2082
11.47	36.034	103.328	3.0028	1239.9	351.27	849.6	5.735	8.2226
11.48	36.065	103.508	3.0055	1242.1	351.89	852.6	5.740	8.2369
11.49	36.097	103.688	3.0081	1244.3	352.50	855.6	5.745	8.2513
11.50	36.128	103.869	3.0107	1246.4	353.11	858.5	5.750	8.2656

Properties of Tubes and Round Bars (Continued) **11.50** inches **12.00** inches

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches	Circumference in inches	Area cross section sq. in.	Per foot length			Moment of inertia	Distance from axis to farthest fiber	Radius of gyration squared
			Surface sq. ft.	Volume cu. in.	Weight, lbs. steel			
D	*C*	*A*	*S*	*V*	*W*	*I*	*y*	R^2
11.50	36.128	103.869	3.0107	1246.4	353.11	858.5	5.750	8.2656
11.51	36.160	104.050	3.0133	1248.6	353.73	861.5	5.755	8.2800
11.52	36.191	104.231	3.0159	1250.8	354.34	864.5	5.760	8.2944
11.53	36.223	104.412	3.0185	1252.9	354.96	867.5	5.765	8.3088
11.54	36.254	104.593	3.0212	1255.1	355.57	870.6	5.770	8.3232
11.55	36.285	104.774	3.0238	1257.3	356.19	873.6	5.775	8.3377
11.56	36.317	104.956	3.0264	1259.5	356.81	876.6	5.780	8.3521
11.57	36.348	105.137	3.0290	1261.6	357.42	879.6	5.785	8.3666
11.58	36.380	105.319	3.0316	1263.8	358.04	882.7	5.790	8.3810
11.59	36.411	105.501	3.0343	1266.0	358.66	885.7	5.795	8.3955
11.60	36.442	105.683	3.0369	1268.2	359.28	888.8	5.800	8.4100
11.61	36.474	105.865	3.0395	1270.4	359.90	891.9	5.805	8.4245
11.62	36.505	106.048	3.0421	1272.6	360.52	894.9	5.810	8.4390
11.63	36.537	106.231	3.0447	1274.8	361.14	898.0	5.815	8.4536
11.64	36.568	106.413	3.0473	1277.0	361.76	901.1	5.820	8.4681
11.65	36.600	106.596	3.0500	1279.2	362.38	904.2	5.825	8.4827
11.66	36.631	106.779	3.0526	1281.4	363.01	907.3	5.830	8.4972
11.67	36.662	106.963	3.0552	1283.6	363.63	910.4	5.835	8.5118
11.68	36.694	107.146	3.0578	1285.8	364.25	913.6	5.840	8.5264
11.69	36.725	107.329	3.0604	1288.0	364.88	916.7	5.845	8.5410
11.70	36.757	107.513	3.0631	1290.2	365.50	919.8	5.850	8.5556
11.71	36.788	107.697	3.0657	1292.4	366.13	923.0	5.855	8.5703
11.72	36.819	107.881	3.0683	1294.6	366.75	926.1	5.860	8.5849
11.73	36.851	108.065	3.0709	1296.8	367.38	929.3	5.865	8.5996
11.74	36.882	108.250	3.0735	1299.0	368.01	932.5	5.870	8.6142
11.75	36.914	108.434	3.0761	1301.2	368.63	935.7	5.875	8.6289
11.76	36.945	108.619	3.0788	1303.4	369.26	938.9	5.880	8.6436
11.77	36.977	108.803	3.0814	1305.6	369.89	942.1	5.885	8.6583
11.78	37.008	108.988	3.0840	1307.9	370.52	945.3	5.890	8.6730
11.79	37.039	109.174	3.0866	1310.1	371.15	948.5	5.895	8.6878
11.80	37.071	109.359	3.0892	1312.3	371.78	951.7	5.900	8.7025
11.81	37.102	109.544	3.0919	1314.5	372.41	954.9	5.905	8.7173
11.82	37.134	109.730	3.0945	1316.8	373.04	958.2	5.910	8.7320
11.83	37.165	109.916	3.0971	1319.0	373.67	961.4	5.915	8.7468
11.84	37.196	110.102	3.0997	1321.2	374.30	964.7	5.920	8.7616
11.85	37.228	110.288	3.1023	1323.5	374.93	967.9	5.925	8.7764
11.86	37.259	110.474	3.1049	1325.7	375.57	971.2	5.930	8.7912
11.87	37.291	110.660	3.1076	1327.9	376.20	974.5	5.935	8.8061
11.88	37.322	110.847	3.1102	1330.2	376.83	977.8	5.940	8.8209
11.89	37.354	111.033	3.1128	1332.4	377.47	981.1	5.945	8.8358
11.90	37.385	111.220	3.1154	1334.6	378.10	984.4	5.950	8.8506
11.91	37.416	111.407	3.1180	1336.9	378.74	987.7	5.955	8.8655
11.92	37.448	111.594	3.1206	1339.1	379.38	991.0	5.960	8.8804
11.93	37.479	111.782	3.1233	1341.4	380.01	994.3	5.965	8.8953
11.94	37.511	111.969	3.1259	1343.6	380.65	997.7	5.970	8.9102
11.95	37.542	112.157	3.1285	1345.9	381.29	1001.0	5.975	8.9252
11.96	37.573	112.345	3.1311	1348.1	381.93	1004.4	5.980	8.9401
11.97	37.605	112.533	3.1337	1350.4	382.57	1007.7	5.985	8.9551
11.98	37.636	112.721	3.1364	1352.6	383.21	1011.1	5.990	8.9700
11.99	37.668	112.909	3.1390	1354.9	383.85	1014.5	5.995	8.9850
12.00	37.699	113.097	3.1416	1357.2	384.49	1017.9	6.000	9.0000

Properties of Tubes and Round Bars (Continued) **12.00** inches **12.50** inches

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches	Circumference in inches	Area cross section sq. in.	Per foot length			Moment of inertia	Distance from axis to farthest fiber	Radius of gyration squared
			Surface sq. ft.	Volume cu. in.	Weight, lbs. steel			
D	C	A	S	V	W	I	y	R^2
12.00	37.699	113.097	3.1416	1357.2	384.49	1017.9	6.000	9.0000
12.01	37.731	113.286	3.1442	1359.4	385.13	1021.3	6.005	9.0150
12.02	37.762	113.475	3.1468	1361.7	385.77	1024.7	6.010	9.0300
12.03	37.793	113.664	3.1494	1364.0	386.41	1028.1	6.015	9.0451
12.04	37.825	113.853	3.1521	1366.2	387.05	1031.5	6.020	9.0601
12.05	37.856	114.042	3.1547	1368.5	387.70	1034.9	6.025	9.0752
12.06	37.888	114.231	3.1573	1370.8	388.34	1038.4	6.030	9.0902
12.07	37.919	114.421	3.1599	1373.0	388.98	1041.8	6.035	9.1053
12.08	37.950	114.610	3.1625	1375.3	389.63	1045.3	6.040	9.1204
12.09	37.982	114.800	3.1652	1377.6	390.27	1048.8	6.045	9.1355
12.10	38.013	114.990	3.1678	1379.9	390.92	1052.2	6.050	9.1506
12.11	38.045	115.180	3.1704	1382.2	391.57	1055.7	6.055	9.1658
12.12	38.076	115.371	3.1730	1384.4	392.21	1059.2	6.060	9.1809
12.13	38.108	115.561	3.1756	1386.7	392.86	1062.7	6.065	9.1961
12.14	38.139	115.752	3.1782	1389.0	393.51	1066.2	6.070	9.2112
12.15	38.170	115.942	3.1809	1391.3	394.16	1069.7	6.075	9.2264
12.16	38.202	116.133	3.1835	1393.6	394.81	1073.3	6.080	9.2416
12.17	38.233	116.324	3.1861	1395.9	395.46	1076.8	6.085	9.2568
12.18	38.265	116.516	3.1887	1398.2	396.11	1080.3	6.090	9.2720
12.19	38.296	116.707	3.1913	1400.5	396.76	1083.9	6.095	9.2873
12.20	38.327	116.899	3.1940	1402.8	397.41	1087.5	6.100	9.3025
12.21	38.359	117.090	3.1966	1405.1	398.06	1091.0	6.105	9.3178
12.22	38.390	117.282	3.1992	1407.4	398.71	1094.6	6.110	9.3330
12.23	38.422	117.474	3.2018	1409.7	399.37	1098.2	6.115	9.3483
12.24	38.453	117.666	3.2044	1412.0	400.02	1101.8	6.120	9.3636
12.25	38.485	117.859	3.2070	1414.3	400.67	1105.4	6.125	9.3789
12.26	38.516	118.051	3.2097	1416.6	401.33	1109.0	6.130	9.3942
12.27	38.547	118.244	3.2123	1418.9	401.98	1112.6	6.135	9.4096
12.28	38.579	118.437	3.2149	1421.2	402.64	1116.3	6.140	9.4249
12.29	38.610	118.630	3.2175	1423.6	403.29	1119.9	6.145	9.4403
12.30	38.642	118.823	3.2201	1425.9	403.95	1123.5	6.150	9.4556
12.31	38.673	119.016	3.2228	1428.2	404.61	1127.2	6.155	9.4710
12.32	38.704	119.210	3.2254	1430.5	405.27	1130.9	6.160	9.4864
12.33	38.736	119.403	3.2280	1432.8	405.92	1134.5	6.165	9.5018
12.34	38.767	119.597	3.2306	1435.2	406.58	1138.2	6.170	9.5172
12.35	38.799	119.791	3.2332	1437.5	407.24	1141.9	6.175	9.5327
12.36	38.830	119.985	3.2358	1439.8	407.90	1145.6	6.180	9.5481
12.37	38.862	120.179	3.2385	1442.2	408.56	1149.3	6.185	9.5636
12.38	38.893	120.374	3.2411	1444.5	409.22	1153.1	6.190	9.5790
12.39	38.924	120.568	3.2437	1446.8	409.88	1156.8	6.195	9.5945
12.40	38.956	120.763	3.2463	1449.2	410.55	1160.5	6.200	9.6100
12.41	38.987	120.958	3.2489	1451.5	411.21	1164.3	6.205	9.6255
12.42	39.019	121.153	3.2515	1453.8	411.87	1168.0	6.210	9.6410
12.43	39.050	121.348	3.2542	1456.2	412.53	1171.8	6.215	9.6566
12.44	39.081	121.543	3.2568	1458.5	413.20	1175.6	6.220	9.6721
12.45	39.113	121.739	3.2594	1460.9	413.86	1179.4	6.225	9.6877
12.46	39.144	121.934	3.2620	1463.2	414.53	1183.2	6.230	9.7032
12.47	39.176	122.130	3.2646	1465.6	415.19	1187.0	6.235	9.7188
12.48	39.207	122.326	3.2673	1467.9	415.86	1190.8	6.240	9.7344
12.49	39.238	122.522	3.2699	1470.3	416.53	1194.6	6.245	9.7500
12.50	39.270	122.718	3.2725	1472.6	417.19	1198.4	6.250	9.7656

Properties of Tubes and Round Bars (Continued) **12.50** inches **13.00** inches

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches *D*	Circumference in inches *C*	Area cross section sq. in. *A*	Per foot length: Surface sq. ft. *S*	Per foot length: Volume cu. in. *V*	Per foot length: Weight, lbs. steel *W*	Moment of inertia *I*	Distance from axis to farthest fiber *y*	Radius of gyration squared R^2
12.50	39.270	122.718	3.2725	1472.6	417.19	1198.4	6.250	9.7656
12.51	39.301	122.915	3.2751	1475.0	417.86	1202.3	6.255	9.7813
12.52	39.333	123.111	3.2777	1477.3	418.53	1206.1	6.260	9.7969
12.53	39.364	123.308	3.2803	1479.7	419.20	1210.0	6.265	9.8126
12.54	39.396	123.505	3.2830	1482.1	419.87	1213.8	6.270	9.8282
12.55	39.427	123.702	3.2856	1484.4	420.54	1217.7	6.275	9.8439
12.56	39.458	123.899	3.2882	1486.8	421.21	1221.6	6.280	9.8596
12.57	39.490	124.097	3.2908	1489.2	421.88	1225.5	6.285	9.8753
12.58	39.521	124.294	3.2934	1491.5	422.55	1229.4	6.290	9.8910
12.59	39.553	124.492	3.2961	1493.9	423.22	1233.3	6.295	9.9068
12.60	39.584	124.690	3.2987	1496.3	423.90	1237.2	6.300	9.9225
12.61	39.615	124.888	3.3013	1498.7	424.57	1241.2	6.305	9.9383
12.62	39.647	125.086	3.3039	1501.0	425.24	1245.1	6.310	9.9540
12.63	39.678	125.284	3.3065	1503.4	425.92	1249.1	6.315	9.9698
12.64	39.710	125.483	3.3091	1505.8	426.59	1253.0	6.320	9.9856
12.65	39.741	125.681	3.3118	1508.2	427.27	1257.0	6.325	10.0014
12.66	39.773	125.880	3.3144	1510.6	427.94	1261.0	6.330	10.0172
12.67	39.804	126.079	3.3170	1512.9	428.62	1265.0	6.335	10.0331
12.68	39.835	126.278	3.3196	1515.3	429.30	1269.0	6.340	10.0489
12.69	39.867	126.477	3.3222	1517.7	429.97	1273.0	6.345	10.0648
12.70	39.898	126.677	3.3249	1520.1	430.65	1277.0	6.350	10.0806
12.71	39.930	126.876	3.3275	1522.5	431.33	1281.0	6.355	10.0965
12.72	39.961	127.076	3.3301	1524.9	432.01	1285.0	6.360	10.1124
12.73	39.992	127.276	3.3327	1527.3	432.69	1289.1	6.365	10.1283
12.74	40.024	127.476	3.3353	1529.7	433.37	1293.1	6.370	10.1442
12.75	40.055	127.68	3.3379	1532.1	434.05	1297.2	6.375	10.1602
12.76	40.087	127.88	3.3406	1534.5	434.73	1301.3	6.380	10.1761
12.77	40.118	128.08	3.3432	1536.9	435.41	1305.4	6.385	10.1921
12.78	40.150	128.28	3.3458	1539.3	436.09	1309.5	6.390	10.2080
12.79	40.181	128.48	3.3484	1541.7	436.78	1313.6	6.395	10.2240
12.80	40.212	128.68	3.3510	1544.2	437.46	1317.7	6.400	10.2400
12.81	40.244	128.88	3.3537	1546.6	438.14	1321.8	6.405	10.2560
12.82	40.275	129.08	3.3563	1549.0	438.83	1325.9	6.410	10.2720
12.83	40.307	129.28	3.3589	1551.4	439.51	1330.1	6.415	10.2881
12.84	40.338	129.49	3.3615	1553.8	440.20	1334.2	6.420	10.3041
12.85	40.369	129.69	3.3641	1556.2	440.88	1338.4	6.425	10.3202
12.86	40.401	129.89	3.3667	1558.7	441.57	1342.6	6.430	10.3362
12.87	40.432	130.09	3.3694	1561.1	442.26	1346.7	6.435	10.3523
12.88	40.464	130.29	3.3720	1563.5	442.94	1350.9	6.440	10.3684
12.89	40.495	130.50	3.3746	1565.9	443.63	1355.1	6.445	10.3845
12.90	40.527	130.70	3.3772	1568.4	444.32	1359.3	6.450	10.4006
12.91	40.558	130.90	3.3798	1570.8	445.01	1363.6	6.455	10.4168
12.92	40.589	131.10	3.3824	1573.2	445.70	1367.8	6.460	10.4329
12.93	40.621	131.31	3.3851	1575.7	446.39	1372.0	6.465	10.4491
12.94	40.652	131.51	3.3877	1578.1	447.08	1376.3	6.470	10.4652
12.95	40.684	131.71	3.3903	1580.6	447.77	1380.5	6.475	10.4814
12.96	40.715	131.92	3.3929	1583.0	448.46	1384.8	6.480	10.4976
12.97	40.746	132.12	3.3955	1585.4	449.16	1389.1	6.485	10.5138
12.98	40.778	132.32	3.3982	1587.9	449.85	1393.4	6.490	10.5300
12.99	40.809	132.53	3.4008	1590.3	450.54	1397.7	6.495	10.5463
13.00	40.841	132.73	3.4034	1592.8	451.24	1402.0	6.500	10.5625

Properties of Tubes and Round Bars (Continued) **13.00 inches 13.50 inches**

For Tubes use differences for A, W, I and V (for volume of wall only), sum for R^2, and direct tabular values for C, S, y and V (for capacity). For Round Bars use all tabular values direct.

Diam. in inches D	Circumference in inches C	Area cross section sq. in. A	Per foot length: Surface sq. ft. S	Per foot length: Volume cu. in. V	Per foot length: Weight, lbs. steel W	Moment of inertia I	Distance from axis to farthest fiber y	Radius of gyration squared R^2
13.00	40.841	132.73	3.4034	1592.8	451.24	1402.0	6.500	10.5625
13.01	40.872	132.94	3.4060	1595.2	451.93	1406.3	6.505	10.5788
13.02	40.904	133.14	3.4086	1597.7	452.63	1410.6	6.510	10.5950
13.03	40.935	133.35	3.4112	1600.1	453.32	1415.0	6.515	10.6113
13.04	40.966	133.55	3.4139	1602.6	454.02	1419.3	6.520	10.6276
13.05	40.998	133.76	3.4165	1605.1	454.71	1423.7	6.525	10.6439
13.06	41.029	133.96	3.4191	1607.5	455.41	1428.0	6.530	10.6602
13.07	41.061	134.17	3.4217	1610.0	456.11	1432.4	6.535	10.6766
13.08	41.092	134.37	3.4243	1612.5	456.81	1436.8	6.540	10.6929
13.09	41.123	134.58	3.4270	1614.9	457.51	1441.2	6.545	10.7093
13.10	41.155	134.78	3.4296	1617.4	458.21	1445.6	6.550	10.7256
13.11	41.186	134.99	3.4322	1619.9	458.91	1450.0	6.555	10.7420
13 12	41.218	135.19	3.4348	1622.3	459.61	1454.5	6.560	10.7584
13.13	41.249	135.40	3.4374	1624.8	460.31	1458.9	6.565	10.7748
13.14	41.281	135.61	3.4400	1627.3	461.01	1463.4	6.570	10.7912
13.15	41.312	135.81	3.4427	1629.8	461.71	1467.8	6.575	10.8077
13.16	41.343	136.02	3.4453	1632.2	462.41	1472.3	6.580	10.8241
13.17	41.375	136.23	3.4479	1634.7	463.12	1476.8	6.585	10.8406
13.18	41.406	136.43	3.4505	1637.2	463.82	1481.3	6.590	10.8570
13.19	41.438	136.64	3.4531	1639.7	464.52	1485.8	6.595	10.8735
13.20	41.469	136.85	3.4558	1642.2	465.23	1490.3	6.600	10.8900
13.21	41.500	137.06	3.4584	1644.7	465.93	1494.8	6.605	10.9065
13.22	41.532	137.26	3.4610	1647.2	466.64	1499.3	6.610	10.9230
13.23	41.563	137.47	3.4636	1649.6	467.34	1503.9	6.615	10.9396
13.24	41.595	137.68	3.4662	1652.1	468.05	1508.4	6.620	10.9561
13.25	41.626	137.89	3.4688	1654.6	468.76	1513.0	6.625	10.9727
13.26	41.658	138.09	3.4715	1657.1	469.47	1517.6	6.630	10.9892
13.27	41.689	138.30	3.4741	1659.6	470.18	1522.1	6.635	11.0058
13.28	41.720	138.51	3.4767	1662.1	470.88	1526.7	6.640	11.0224
13.29	41.752	138.72	3.4793	1664.6	471.59	1531.3	6.645	11.0390
13.30	41.783	138.93	3.4819	1667.1	472.30	1535.9	6.650	11.0556
13.31	41.815	139.14	3.4845	1669.7	473.01	1540.6	6.655	11.0723
13.32	41.846	139.35	3.4872	1672.2	473.72	1545.2	6.660	11.0889
13.33	41.877	139.56	3.4898	1674.7	474.44	1549.9	6.665	11.1056
13.34	41.909	139.77	3.4924	1677.2	475.15	1554.5	6.670	11.1222
13.35	41.940	139.98	3.4950	1679.7	475.86	1559.2	6.675	11.1389
13.36	41.972	140.19	3.4976	1682.2	476.57	1563.8	6.680	11.1556
13.37	42.003	140.40	3.5003	1684.7	477.29	1568.5	6.685	11.1723
13.38	42.035	140.61	3.5029	1687.3	478.00	1573.2	6.690	11.1890
13.39	42.066	140.82	3.5055	1689.8	478.72	1578.0	6.695	11.2058
13.40	42.097	141.03	3.5081	1692.3	479.43	1582.7	6.700	11.2225
13.41	42.129	141.24	3.5107	1694.8	480.15	1587.4	6.705	11.2393
13.42	42.160	141.45	3.5133	1697.4	480.86	1592.1	6.710	11.2560
13.43	42.192	141.66	3.5160	1699.9	481.58	1596.9	6.715	11.2728
13.44	42.223	141.87	3.5186	1702.4	482.30	1601.6	6.720	11.2896
13.45	42.254	142.08	3.5212	1705.0	483.02	1606.4	6.725	11.3064
13.46	42.286	142.29	3.5238	1707.5	483.74	1611.2	6.730	11.3232
13.47	42.317	142.50	3.5264	1710.0	484.45	1616.0	6.735	11.3401
13.48	42.349	142.72	3.5291	1712.6	485.17	1620.8	6.740	11.3569
13.49	42.380	142.93	3.5317	1715.1	485.89	1625.6	6.745	11.3738
13.50	42.412	143.14	3.5343	1717.7	486.61	1630.4	6.750	11.3906

Properties of Tubes and Round Bars (Continued) **13.50** inches **14.00** inches

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches *D*	Circumference in inches *C*	Area cross section sq. in. *A*	Per foot length: Surface sq. ft. *S*	Per foot length: Volume cu. in. *V*	Per foot length: Weight, lbs. steel *W*	Moment of inertia *I*	Distance from axis to farthest fiber *y*	Radius of gyration squared R^2
13.50	42.412	143.14	3.5343	1717.7	486.61	1630.4	6.750	11.3906
13.51	42.443	143.35	3.5369	1720.2	487.34	1635.3	6.755	11.4075
13.52	42.474	143.56	3.5395	1722.8	488.06	1640.1	6.760	11.4244
13.53	42.506	143.78	3.5421	1725.3	488.78	1645.0	6.765	11.4413
13.54	42.537	143.99	3.5448	1727.9	489.50	1649.8	6.770	11.4582
13.55	42.569	144.20	3.5474	1730.4	490.23	1654.7	6.775	11.4752
13.56	42.600	144.41	3.5500	1733.0	490.95	1659.6	6.780	11.4921
13.57	42.631	144.63	3.5526	1735.5	491.67	1664.5	6.785	11.5091
13.58	42.663	144.84	3.5552	1738.1	492.40	1669.4	6.790	11.5260
13.59	42.694	145.05	3.5579	1740.6	493.12	1674.4	6.795	11.5430
13.60	42.726	145.27	3.5605	1743.2	493.85	1679.3	6.800	11.5600
13.61	42.757	145.48	3.5631	1745.8	494.58	1684.2	6.805	11.5770
13.62	42.788	145.69	3.5657	1748.3	495.30	1689.2	6.810	11.5940
13.63	42.820	145.91	3.5683	1750.9	496.03	1694.2	6.815	11.6111
13.64	42.851	146.12	3.5709	1753.5	496.76	1699.1	6.820	11.6281
13.65	42.883	146.34	3.5736	1756.0	497.49	1704.1	6.825	11.6452
13.66	42.914	146.55	3.5762	1758.6	498.22	1709.1	6.830	11.6622
13.67	42.946	146.77	3.5788	1761.2	498.95	1714.1	6.835	11.6793
13.68	42.977	146.98	3.5814	1763.8	499.68	1719.1	6.840	11.6964
13.69	43.008	147.20	3.5840	1766.4	500.41	1724.2	6.845	11.7135
13.70	43.040	147.41	3.5867	1768.9	501.14	1729.2	6.850	11.7306
13.71	43.071	147.63	3.5893	1771.5	501.87	1734.3	6.855	11.7478
13.72	43.103	147.84	3.5919	1774.1	502.60	1739.3	6.860	11.7649
13.73	43.134	148.06	3.5945	1776.7	503.34	1744.4	6.865	11.7821
13.74	43.165	148.27	3.5971	1779.3	504.07	1749.5	6.870	11.7992
13.75	43.197	148.49	3.5997	1781.9	504.80	1754.6	6.875	11.8164
13.76	43.228	148.71	3.6024	1784.5	505.54	1759.7	6.880	11.8336
13.77	43.260	148.92	3.6050	1787.1	506.27	1764.8	6.885	11.8508
13.78	43.291	149.14	3.6076	1789.7	507.01	1770.0	6.890	11.8680
13.79	43.323	149.35	3.6102	1792.3	507.75	1775.1	6.895	11.8853
13.80	43.354	149.57	3.6128	1794.9	508.48	1780.3	6.900	11.9025
13.81	43.385	149.79	3.6154	1797.5	509.22	1785.4	6.905	11.9198
13.82	43.417	150.01	3.6181	1800.1	509.96	1790.6	6.910	11.9370
13.83	43.448	150.22	3.6207	1802.7	510.70	1795.8	6.915	11.9543
13.84	43.480	150.44	3.6233	1805.3	511.43	1801.0	6.920	11.9716
13.85	43.511	150.66	3.6259	1807.9	512.17	1806.2	6.925	11.9889
13.86	43.542	150.87	3.6285	1810.5	512.91	1811.4	6.930	12.0062
13.87	43.574	151.09	3.6312	1813.1	513.65	1816.7	6.935	12.0236
13.88	43.605	151.31	3.6338	1815.7	514.39	1821.9	6.940	12.0409
13.89	43.637	151.53	3.6364	1818.3	515.14	1827.2	6.945	12.0583
13.90	43.668	151.75	3.6390	1821.0	515.88	1832.4	6.950	12.0756
13.91	43.700	151.97	3.6416	1823.6	516.62	1837.7	6.955	12.0930
13.92	43.731	152.18	3.6442	1826.2	517.36	1843.0	6.960	12.1104
13.93	43.762	152.40	3.6469	1828.8	518.11	1848.3	6.965	12.1278
13.94	43.794	152.62	3.6495	1831.5	518.85	1853.6	6.970	12.1452
13.95	43.825	152.84	3.6521	1834.1	519.60	1858.9	6.975	12.1627
13.96	43.857	153.06	3.6547	1836.7	520.34	1864.3	6.980	12.1801
13.97	43.888	153.28	3.6573	1839.3	521.09	1869.6	6.985	12.1976
13.98	43.919	153.50	3.6600	1842.0	521.83	1875.0	6.990	12.2150
13.99	43.951	153.72	3.6626	1844.6	522.58	1880.4	6.995	12.2325
14.00	43.982	153.94	3.6652	1847.3	523.33	1885.7	7.000	12.2500

Properties of Tubes and Round Bars (Continued) **14.00** inches **14.50** inches

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches *D*	Circumference in inches *C*	Area cross section sq. in. *A*	Per foot length: Surface sq. ft. *S*	Per foot length: Volume cu. in. *V*	Per foot length: Weight, lbs. steel *W*	Moment of inertia *I*	Distance from axis to farthest fiber *y*	Radius of gyration squared R^2
14.00	43.982	153.94	3.6652	1847.3	523.33	1885.7	7.000	12.2500
14.01	44.014	154.16	3.6678	1849.9	524.08	1891.1	7.005	12.2675
14.02	44.045	154.38	3.6704	1852.5	524.82	1896.5	7.010	12.2850
14.03	44.077	154.60	3.6730	1855.2	525.57	1902.0	7.015	12.3026
14.04	44.108	154.82	3.6757	1857.8	526.32	1907.4	7.020	12.3201
14.05	44.139	155.04	3.6783	1860.5	527.07	1912.8	7.025	12.3377
14.06	44.171	155.26	3.6809	1863.1	527.82	1918.3	7.030	12.3552
14.07	44.202	155.48	3.6835	1865.8	528.57	1923.7	7.035	12.3728
14.08	44.234	155.70	3.6861	1868.4	529.33	1929.2	7.040	12.3904
14.09	44.265	155.92	3.6888	1871.1	530.08	1934.7	7.045	12.4080
14.10	44.296	156.15	3.6914	1873.7	530.83	1940.2	7.050	12.4256
14.11	44.328	156.37	3.6940	1876.4	531.58	1945.7	7.055	12.4433
14.12	44.359	156.59	3.6966	1879.1	532.34	1951.2	7.060	12.4609
14.13	44.391	156.81	3.6992	1881.7	533.09	1956.8	7.065	12.4786
14.14	44.422	157.03	3.7018	1884.4	533.85	1962.3	7.070	12.4962
14.15	44.454	157.25	3.7045	1887.1	534.60	1967.9	7.075	12.5139
14.16	44.485	157.48	3.7071	1889.7	535.36	1973.4	7.080	12.5316
14.17	44.516	157.70	3.7097	1892.4	536.11	1979.0	7.085	12.5493
14.18	44.548	157.92	3.7123	1895.1	536.87	1984.6	7.090	12.5670
14.19	44.579	158.14	3.7149	1897.7	537.63	1990.2	7.095	12.5848
14.20	44.611	158.37	3.7176	1900.4	538.39	1995.8	7.100	12.6025
14.21	44.642	158.59	3.7202	1903.1	539.15	2001.5	7.105	12.6203
14.22	44.673	158.81	3.7228	1905.8	539.90	2007.1	7.110	12.6380
14.23	44.705	159.04	3.7254	1908.5	540.66	2012.8	7.115	12.6558
14.24	44.736	159.26	3.7280	1911.1	541.42	2018.4	7.120	12.6736
14.25	44.768	159.48	3.7306	1913.8	542.18	2024.1	7.125	12.6914
14.26	44.799	159.71	3.7333	1916.5	542.95	2029.8	7.130	12.7092
14.27	44.831	159.93	3.7359	1919.2	543.71	2035.5	7.135	12.7271
14.28	44.862	160.16	3.7385	1921.9	544.47	2041.2	7.140	12.7449
14.29	44.893	160.38	3.7411	1924.6	545.23	2046.9	7.145	12.7628
14.30	44.925	160.61	3.7437	1927.3	546.00	2052.6	7.150	12.7806
14.31	44.956	160.83	3.7463	1930.0	546.76	2058.4	7.155	12.7985
14.32	44.988	161.06	3.7490	1932.7	547.52	2064.2	7.160	12.8164
14.33	45.019	161.28	3.7516	1935.4	548.29	2069.9	7.165	12.8343
14.34	45.050	161.51	3.7542	1938.1	549.06	2075.7	7.170	12.8522
14.35	45.082	161.73	3.7568	1940.8	549.82	2081.5	7.175	12.8702
14.36	45.113	161.96	3.7594	1943.5	550.59	2087.3	7.180	12.8881
14.37	45.145	162.18	3.7621	1946.2	551.35	2093.1	7.185	12.9061
14.38	45.176	162.41	3.7647	1948.9	552.12	2099.0	7.190	12.9240
14.39	45.208	162.63	3.7673	1951.6	552.89	2104.8	7.195	12.9420
14.40	45.239	162.86	3.7699	1954.3	553.66	2110.7	7.200	12.9600
14.41	45.270	163.09	3.7725	1957.0	554.43	2116.5	7.205	12.9780
14.42	45.302	163.31	3.7751	1959.8	555.20	2122.4	7.210	12.9960
14.43	45.333	163.54	3.7778	1962.5	555.97	2128.3	7.215	13.0141
14.44	45.365	163.77	3.7804	1965.2	556.74	2134.2	7.220	13.0321
14.45	45.396	163.99	3.7830	1967.9	557.51	2140.1	7.225	13.0502
14.46	45.427	164.22	3.7856	1970.6	558.28	2146.1	7.230	13.0682
14.47	45.459	164.45	3.7882	1973.4	559.06	2152.0	7.235	13.0863
14.48	45.490	164.67	3.7909	1976.1	559.83	2158.0	7.240	13.1044
14.49	45.522	164.90	3.7935	1978.8	560.60	2163.9	7.245	13.1225
14.50	45.553	165.13	3.7961	1981.6	561.38	2169.9	7.250	13.1406

Properties of Tubes and Round Bars (Continued) **14.50** inches **15.00** inches

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches *D*	Circumference in inches *C*	Area cross section sq. in. *A*	Per foot length: Surface sq. ft. *S*	Per foot length: Volume cu. in. *V*	Per foot length: Weight, lbs. steel *W*	Moment of inertia *I*	Distance from axis to farthest fiber *y*	Radius of gyration squared R^2
14.50	45.553	165.13	3.7961	1981.6	561.38	2169.9	7.250	13.1406
14.51	45.585	165.36	3.7987	1984.3	562.15	2175.9	7.255	13.1588
14.52	45.616	165.59	3.8013	1987.0	562.93	2181.9	7.260	13.1769
14.53	45.647	165.81	3.8039	1989.8	563.70	2187.9	7.265	13.1951
14.54	45.679	166.04	3.8066	1992.5	564.48	2193.9	7.270	13.2132
14.55	45.710	166.27	3.8092	1995.2	565.25	2200.0	7.275	13.2314
14.56	45.742	166.50	3.8118	1998.0	566.03	2206.0	7.280	13.2496
14.57	45.773	166.73	3.8144	2000.7	566.81	2212.1	7.285	13.2678
14.58	45.804	166.96	3.8170	2003.5	567.59	2218.2	7.290	13.2860
14.59	45.836	167.19	3.8197	2006.2	568.37	2224.3	7.295	13.3043
14.60	45.867	167.42	3.8223	2009.0	569.15	2230.4	7.300	13.3225
14.61	45.899	167.64	3.8249	2011.7	569.93	2236.5	7.305	13.3408
14.62	45.930	167.87	3.8275	2014.5	570.71	2242.6	7.310	13.3590
14.63	45.962	168.10	3.8301	2017.3	571.49	2248.8	7.315	13.3773
14.64	45.993	168.33	3.8327	2020.0	572.27	2254.9	7.320	13.3956
14.65	46.024	168.56	3.8354	2022.8	573.05	2261.1	7.325	13.4139
14.66	46.056	168.79	3.8380	2025.5	573.83	2267.3	7.330	13.4322
14.67	46.087	169.02	3.8406	2028.3	574.62	2273.5	7.335	13.4506
14.68	46.119	169.26	3.8432	2031.1	575.40	2279.7	7.340	13.4689
14.69	46.150	169.49	3.8458	2033.8	576.18	2285.9	7.345	13.4873
14.70	46.181	169.72	3.8485	2036.6	576.97	2292.1	7.350	13.5056
14.71	46.213	169.95	3.8511	2039.4	577.75	2298.4	7.355	13.5240
14.72	46.244	170.18	3.8537	2042.1	578.54	2304.6	7.360	13.5424
14.73	46.276	170.41	3.8563	2044.9	579.33	2310.9	7.365	13.5608
14.74	46.307	170.64	3.8589	2047.7	580.11	2317.2	7.370	13.5792
14.75	46.338	170.87	3.8615	2050.5	580.90	2323.5	7.375	13.5977
14.76	46.370	171.10	3.8642	2053.3	581.69	2329.8	7.380	13.6161
14.77	46.401	171.34	3.8668	2056.0	582.48	2336.1	7.385	13.6346
14.78	46.433	171.57	3.8694	2058.8	583.27	2342.4	7.390	13.6530
14.79	46.464	171.80	3.8720	2061.6	584.06	2348.8	7.395	13.6715
14.80	46.496	172.03	3.8746	2064.4	584.85	2355.1	7.400	13.6900
14.81	46.527	172.27	3.8772	2067.2	585.64	2361.5	7.405	13.7085
14.82	46.558	172.50	3.8799	2070.0	586.43	2367.9	7.410	13.7270
14.83	46.590	172.73	3.8825	2072.8	587.22	2374.3	7.415	13.7456
14.84	46.621	172.96	3.8851	2075.6	588.01	2380.7	7.420	13.7641
14.85	46.653	173.20	3.8877	2078.4	588.80	2387.1	7.425	13.7827
14.86	46.684	173.43	3.8903	2081.2	589.60	2393.6	7.430	13.8012
14.87	46.715	173.66	3.8930	2084.0	590.39	2400.0	7.435	13.8198
14.88	46.747	173.90	3.8956	2086.8	591.19	2406.5	7.440	13.8384
14.89	46.778	174.13	3.8982	2089.6	591.98	2412.9	7.445	13.8570
14.90	46.810	174.37	3.9008	2092.4	592.78	2419.4	7.450	13.8756
14.91	46.841	174.60	3.9034	2095.2	593.57	2425.9	7.455	13.8943
14.92	46.873	174.83	3.9060	2098.0	594.37	2432.5	7.460	13.9129
14.93	46.904	175.07	3.9087	2100.8	595.16	2439.0	7.465	13.9316
14.94	46.935	175.30	3.9113	2103.6	595.96	2445.5	7.470	13.9502
14.95	46.967	175.54	3.9139	2106.5	596.76	2452.1	7.475	13.9689
14.96	46.998	175.77	3.9165	2109.3	597.56	2458.6	7.480	13.9876
14.97	47.030	176.01	3.9191	2112.1	598.36	2465.2	7.485	14.0063
14.98	47.061	176.24	3.9218	2114.9	599.16	2471.8	7.490	14.0250
14.99	47.092	176.48	3.9244	2117.7	599.96	2478.4	7.495	14.0438
15.00	47.124	176.71	3.9270	2120.6	600.76	2485.1	7.500	14.0625

Properties of Tubes and Round Bars (Continued) 15.00 inches / 15.50 inches

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches D	Circumference in inches C	Area cross section sq. in. A	Per foot length: Surface sq. ft. S	Per foot length: Volume cu. in. V	Per foot length: Weight, lbs. steel W	Moment of inertia I	Distance from axis to farthest fiber y	Radius of gyration squared R^2
15.00	47.124	176.71	3.9270	2120.6	600.76	2485.1	7.500	14.0625
15.01	47.155	176.95	3.9296	2123.4	601.56	2491.7	7.505	14.0813
15.02	47.187	177.19	3.9322	2126.2	602.36	2498.3	7.510	14.1000
15.03	47.218	177.42	3.9348	2129.1	603.16	2505.0	7.515	14.1188
15.04	47.250	177.66	3.9375	2131.9	603.97	2511.7	7.520	14.1376
15.05	47.281	177.89	3.9401	2134.7	604.77	2518.4	7.525	14.1564
15.06	47.312	178.13	3.9427	2137.6	605.57	2525.0	7.530	14.1752
15.07	47.344	178.37	3.9453	2140.4	606.38	2531.8	7.535	14.1941
15.08	47.375	178.60	3.9479	2143.3	607.18	2538.5	7.540	14.2129
15.09	47.407	178.84	3.9506	2146.1	607.99	2545.2	7.545	14.2318
15.10	47.438	179.08	3.9532	2148.9	608.80	2552.0	7.550	14.2506
15.11	47.469	179.32	3.9558	2151.8	609.60	2558.7	7.555	14.2695
15.12	47.501	179.55	3.9584	2154.6	610.41	2565.5	7.560	14.2884
15.13	47.532	179.79	3.9610	2157.5	611.22	2572.3	7.565	14.3073
15.14	47.564	180.03	3.9636	2160.3	612.03	2579.1	7.570	14.3262
15.15	47.595	180.27	3.9663	2163.2	612.83	2586.0	7.575	14.3452
15.16	47.627	180.50	3.9689	2166.1	613.64	2592.8	7.580	14.3641
15.17	47.658	180.74	3.9715	2168.9	614.45	2599.6	7.585	14.3831
15.18	47.689	180.98	3.9741	2171.8	615.26	2606.5	7.590	14.4020
15.19	47.721	181.22	3.9767	2174.6	616.07	2613.4	7.595	14.4210
15.20	47.752	181.46	3.9794	2177.5	616.89	2620.3	7.600	14.4400
15.21	47.784	181.70	3.9820	2180.4	617.70	2627.2	7.605	14.4590
15.22	47.815	181.94	3.9846	2183.2	618.51	2634.1	7.610	14.4780
15.23	47.846	182.18	3.9872	2186.1	619.32	2641.0	7.615	14.4971
15.24	47.878	182.41	3.9898	2189.0	620.14	2648.0	7.620	14.5161
15.25	47.909	182.65	3.9924	2191.8	620.95	2654.9	7.625	14.5352
15.26	47.941	182.89	3.9951	2194.7	621.77	2661.9	7.630	14.5542
15.27	47.972	183.13	3.9977	2197.6	622.58	2668.9	7.635	14.5733
15.28	48.004	183.37	4.0003	2200.5	623.40	2675.9	7.640	14.5924
15.29	48.035	183.61	4.0029	2203.4	624.21	2682.9	7.645	14.6115
15.30	48.066	183.85	4.0055	2206.2	625.03	2689.9	7.650	14.6306
15.31	48.098	184.09	4.0081	2209.1	625.85	2696.9	7.655	14.6498
15.32	48.129	184.33	4.0108	2212.0	626.66	2704.0		14.6689
15.33	48.161	184.57	4.0134	2214.9	627.48	2711.1		14.6881
15.34	48.192	184.81	4.0160	2217.8	628.30	2718.1		14.7072
15.35	48.223	185.06	4.0186	2220.7	629.12	2725.2		14.7264
15.36	48.255	185.30	4.0212	2223.6	629.94	2732.3		14.7456
15.37	48.286	185.54	4.0239	2226.5	630.76	2739.5		14.7648
15.38	48.318	185.78	4.0265	2229.4	631.58	2746.6		14.7840
15.39	48.349	186.02	4.0291	2232.3	632.40	2753.8		14.8033
15.40	48.381	186.27	4.0317	2235.2	633.23	2760.9	7.700	14.8225
15.41	48.412	186.51	4.0343	2238.1	634.05	2768.1	7.705	14.8418
15.42	48.443	186.75	4.0369	2241.0	634.87	2775.3	7.710	14.8610
15.43	48.475	186.99	4.0396	2243.9	635.70	2782.5	7.715	14.8803
15.44	48.506	187.23	4.0422	2246.8	636.52	2789.7	7.720	14.8996
15.45	48.538	187.48	4.0448	2249.7	637.35	2797.0	7.725	14.9189
15.46	48.569	187.72	4.0474	2252.6	638.17	2804.2	7.730	14.9382
15.47	48.600	187.96	4.0500	2255.5	639.00	2811.5	7.735	14.9576
15.48	48.632	188.21	4.0527	2258.5	639.82	2818.7	7.740	14.9769
15.49	48.663	188.45	4.0553	2261.4	640.65	2826.0	7.745	14.9963
15.50	48.695	188.69	4.0579	2264.3	641.48	2833.3	7.750	15.0156

Properties of Tubes and Round Bars (Continued) 15.50 inches–16.00 inches

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches *D*	Circumference in inches *C*	Area cross section sq. in. *A*	Per foot length: Surface sq. ft. *S*	Per foot length: Volume cu. in. *V*	Per foot length: Weight, lbs. steel *W*	Moment of inertia *I*	Distance from axis to farthest fiber *y*	Radius of gyration squared R^2
15.50	48.695	188.69	4.0579	2264.3	641.48	2833.3	7.750	15.0156
15.51	48.726	188.94	4.0605	2267.2	642.30	2840.6	7.755	15.0350
15.52	48.758	189.18	4.0631	2270.2	643.13	2848.0	7.760	15.0544
15.53	48.789	189.42	4.0657	2273.1	643.96	2855.3	7.765	15.0738
15.54	48.820	189.67	4.0684	2276.0	644.79	2862.7	7.770	15.0932
15.55	48.852	189.91	4.0710	2278.9	645.62	2870.1	7.775	15.1127
15.56	48.883	190.16	4.0736	2281.9	646.45	2877.5	7.780	15.1321
15.57	48.915	190.40	4.0762	2284.8	647.28	2884.9	7.785	15.1516
15.58	48.946	190.64	4.0788	2287.7	648.12	2892.3	7.790	15.1710
15.59	48.977	190.89	4.0815	2290.7	648.95	2899.7	7.795	15.1905
15.60	49.009	191.13	4.0841	2293.6	649.78	2907.1	7.800	15.2100
15.61	49.040	191.38	4.0867	2296.6	650.61	2914.6	7.805	15.2295
15.62	49.072	191.62	4.0893	2299.5	651.45	2922.1	7.810	15.2490
15.63	49.103	191.87	4.0919	2302.4	652.28	2929.6	7.815	15.2686
15.64	49.135	192.12	4.0945	2305.4	653.12	2937.1	7.820	15.2881
15.65	49.166	192.36	4.0972	2308.3	653.95	2944.6	7.825	15.3077
15.66	49.197	192.61	4.0998	2311.3	654.79	2952.1	7.830	15.3272
15.67	49.229	192.85	4.1024	2314.2	655.63	2959.7	7.835	15.3468
15.68	49.260	193.10	4.1050	2317.2	656.46	2967.3	[illegible]	15.3664
15.69	49.292	193.35	4.1076	2320.2	657.30	2974.8		15.3860
15.70	49.323	193.59	4.1103	2323.1	658.14	2982.4		15.4056
15.71	49.354	193.84	4.1129	2326.1	658.98	2990.0		15.4253
15.72	49.386	194.09	4.1155	2329.0	659.82	2997.6		15.4449
15.73	49.417	194.33	4.1181	2332.0	660.66	3005.3		15.4646
15.74	49.449	194.58	4.1207	2335.0	661.50	3012.9	7.870	15.4842
15.75	49.480	194.83	4.1233	2337.9	662.34	3020.6	7.875	15.5039
15.76	49.512	195.08	4.1260	2340.9	663.18	3028.3	7.880	15.5236
15.77	49.543	195.32	4.1286	2343.9	664.02	3036.0	7.885	15.5433
15.78	49.574	195.57	4.1312	2346.8	664.86	3043.7	7.890	15.5630
15.79	49.606	195.82	4.1338	2349.8	665.71	3051.4	7.895	15.5828
15.80	49.637	196.07	4.1364	2352.8	666.55	3059.1	7.900	15.6025
15.81	49.669	196.32	4.1390	2355.8	667.39	3066.9	7.905	15.6223
15.82	49.700	196.56	4.1417	2358.8	668.24	3074.6	7.910	15.6420
15.83	49.731	196.81	4.1443	2361.7	669.08	3082.4	7.915	15.6618
15.84	49.763	197.06	4.1469	2364.7	669.93	3090.2	7.920	15.6816
15.85	49.794	197.31	4.1495	2367.7	670.77	3098.0	7.925	15.7014
15.86	49.826	197.56	4.1521	2370.7	671.62	3105.9	7.930	15.7212
15.87	49.857	197.81	4.1548	2373.7	672.47	3113.7	7.935	15.7411
15.88	49.888	198.06	4.1574	2376.7	673.32	3121.6	7.940	15.7609
15.89	49.920	198.31	4.1600	2379.7	674.16	3129.4	7.945	15.7808
15.90	49.951	198.56	4.1626	2382.7	675.01	3137.3	7.950	15.8006
15.91	49.983	198.81	4.1652	2385.7	675.86	3145.2	7.955	15.8205
15.92	50.014	199.06	4.1678	2388.7	676.71	3153.1	7.960	15.8404
15.93	50.046	199.31	4.1705	2391.7	677.56	3161.1	7.965	15.8603
15.94	50.077	199.56	4.1731	2394.7	678.41	3169.0	7.970	15.8802
15.95	50.108	199.81	4.1757	2397.7	679.26	3177.0	7.975	15.9002
15.96	50.140	200.06	4.1783	2400.7	680.12	3184.9	7.980	15.9201
15.97	50.171	200.31	4.1809	2403.7	680.97	3192.9	7.985	15.9401
15.98	50.203	200.56	4.1836	2406.7	681.82	3200.9	7.990	15.9600
15.99	50.234	200.81	4.1862	2409.7	682.68	3209.0	7.995	15.9800
16.00	50.265	201.06	4.1888	2412.7	683.53	3217.0	8.000	16.0000

Properties of Tubes and Round Bars (Continued) **16 inches 21 inches**

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches *D*	Circumference in inches *C*	Area cross section sq. in. *A*	Per foot length: Surface sq. ft. *S*	Per foot length: Volume cu. in. *V*	Per foot length: Weight, lbs. steel *W*	Moment of inertia *I*	Distance from axis to farthest fiber *y*	Radius of gyration squared R^2
16	50.265	201.06	4.1888	2412.7	683.53	3217.0	8.000	16.000
1/8	50.658	204.22	4.2215	2450.6	694.25	3318.7	8.063	16.251
1/4	51.051	207.39	4.2542	2488.7	705.06	3422.8	8.125	16.504
3/8	51.444	210.60	4.2870	2527.2	715.95	3529.4	8.188	16.759
1/2	51.836	213.82	4.3197	2565.9	726.92	3638.4	8.250	17.016
5/8	52.229	217.08	4.3524	2604.9	737.97	3749.9	8.313	17.274
3/4	52.622	220.35	4.3851	2644.2	749.11	3863.9	8.375	17.535
7/8	53.014	223.65	4.4179	2683.9	760.34	3980.6	8.438	17.798
17	53.407	226.98	4.4506	2723.8	771.64	4099.8	8.500	18.063
1/8	53.800	230.33	4.4833	2764.0	783.03	4221.7	8.563	18.329
1/4	54.192	233.71	4.5160	2804.5	794.50	4346.4	8.625	18.598
3/8	54.585	237.10	4.5488	2845.3	806.06	4473.7	8.688	18.868
1/2	54.978	240.53	4.5815	2886.3	817.70	4603.9	8.750	19.141
5/8	55.371	243.98	4.6142	2927.7	829.42	4736.8	8.813	19.415
3/4	55.763	247.45	4.6469	2969.4	841.23	4872.6	8.875	19.691
7/8	56.156	250.95	4.6797	3011.4	853.12	5011.3	8.938	19.970
18	56.549	254.47	4.7124	3053.6	865.09	5153.0	9.000	20.250
1/8	56.941	258.02	4.7451	3096.2	877.15	5297.6	9.063	20.532
1/4	57.334	261.59	4.7778	3139.0	889.29	5445.3	9.125	20.816
3/8	57.727	265.18	4.8106	3182.2	901.51	5596.0	9.188	21.103
1/2	58.119	268.80	4.8433	3225.6	913.82	5749.9	9.250	21.391
5/8	58.512	272.45	4.8760	3269.4	926.21	5906.8	9.313	21.681
3/4	58.905	276.12	4.9087	3313.4	938.69	6067.0	9.375	21.973
7/8	59.298	279.81	4.9415	3357.7	951.24	6230.4	9.438	22.267
19	59.690	283.53	4.9742	3402.3	963.88	6397.1	9.500	22.563
1/8	60.083	287.27	5.0069	3447.3	976.61	6567.2	9.563	22.860
1/4	60.476	291.04	5.0396	3492.5	989.42	6740.5	9.625	23.160
3/8	60.868	294.83	5.0724	3538.0	1002.31	6917.3	9.688	23.462
1/2	61.261	298.65	5.1051	3583.8	1015.28	7097.5	9.750	23.766
5/8	61.654	302.49	5.1378	3629.9	1028.34	7281.3	9.813	24.071
3/4	62.046	306.35	5.1705	3676.3	1041.48	7468.6	9.875	24.379
7/8	62.439	310.24	5.2033	3722.9	1054.71	7659.5	9.938	24.688
20	62.832	314.16	5.2360	3769.9	1068.02	7854.0	10.000	25.000
1/8	63.225	318.10	5.2687	3817.2	1081.41	8052.2	10.063	25.313
1/4	63.617	322.06	5.3014	3864.7	1094.88	8254.1	10.125	25.629
3/8	64.010	326.05	5.3342	3912.6	1108.44	8459.8	10.188	25.946
1/2	64.403	330.06	5.3669	3960.8	1122.08	8669.3	10.250	26.266
5/8	64.795	334.10	5.3996	4009.2	1135.81	8882.7	10.313	26.587
3/4	65.188	338.16	5.4323	4058.0	1149.62	9100.0	10.375	26.910
7/8	65.581	342.25	5.4651	4107.0	1163.51	9321.3	10.438	27.235
21	65.973	346.36	5.4978	4156.3	1177.49	9546.6	10.500	27.563

Properties of Tubes and Round Bars (Continued) **21** inches **26** inches

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches *D*	Circumference in inches *C*	Area cross section sq. in. *A*	Per foot length: Surface sq. ft. *S*	Per foot length: Volume cu. in. *V*	Per foot length: Weight, lbs. steel *W*	Moment of inertia *I*	Distance from axis to farthest fiber *y*	Radius of gyration squared R^2
21	65.973	346.36	5.4978	4156.3	1177.49	9546.6	10.500	27.563
⅛	66.366	350.50	5.5305	4206.0	1191.55	9775.9	10.563	27.892
¼	66.759	354.66	5.5632	4255.9	1205.69	10 009.3	10.625	28.223
⅜	67.152	358.84	5.5960	4306.1	1219.92	10 247.0	10.688	28.556
½	67.544	363.05	5.6287	4356.6	1234.23	10 488.7	10.750	28.891
⅝	67.937	367.28	5.6614	4407.4	1248.62	10 734.8	10.813	29.228
¾	68.330	371.54	5.6941	4458.5	1263.10	10 985	10.875	29.566
⅞	68.722	375.83	5.7269	4509.9	1277.66	11 240	10.938	29.907
22	69.115	380.13	5.7596	4561.6	1292.30	11 499	11.000	30.250
⅛	69.508	384.46	5.7923	4613.6	1307.03	11 763	11.063	30.595
¼	69.900	388.82	5.8250	4665.9	1321.84	12 031	11.125	30.941
⅜	70.293	393.20	5.8578	4718.4	1336.73	12 303	11.188	31.290
½	70.686	397.61	5.8905	4771.3	1351.71	12 581	11.250	31.641
⅝	71.079	402.04	5.9232	4824.5	1366.77	12 862	11.313	31.993
¾	71.471	406.49	5.9559	4877.9	1381.91	13 149	11.375	32.348
⅞	71.864	410.97	5.9887	4931.7	1397.14	13 440	11.438	32.704
23	72.257	415.48	6.0214	4985.7	1412.45	13 737	11.500	33.063
⅛	72.649	420.00	6.0541	5040.0	1427.85	14 038	11.563	33.423
¼	73.042	424.56	6.0868	5094.7	1443.32	14 344	11.625	33.785
⅜	73.435	429.13	6.1196	5149.6	1458.88	14 655	11.688	34.149
½	73.827	433.74	6.1523	5204.8	1474.53	14 971	11.750	34.516
⅝	74.220	438.36	6.1850	5260.4	1490.26	15 292	11.813	34.884
¾	74.613	443.01	6.2177	5316.2	1506.07	15 618	11.875	35.254
⅞	75.006	447.69	6.2505	5372.3	1521.96	15 949	11.938	35.626
24	75.398	452.39	6.2832	5428.7	1537.94	16 286	12.000	36.000
⅛	75.791	457.11	6.3159	5485.4	1554.00	16 628	12.063	36.376
¼	76.184	461.86	6.3486	5542.4	1570.15	16 975	12.125	36.754
⅜	76.576	466.64	6.3814	5599.6	1586.38	17 328	12.188	37.134
½	76.969	471.44	6.4141	5657.2	1602.69	17 686	12.250	37.516
⅝	77.362	476.26	6.4468	5715.1	1619.09	18 050	12.313	37.899
¾	77.754	481.11	6.4795	5773.3	1635.57	18 419	12.375	38.285
⅞	78.147	485.98	6.5123	5831.7	1652.13	18 794	12.438	38.673
25	78.540	490.87	6.5450	5890.5	1668.77	19 175	12.500	39.063
⅛	78.933	495.79	6.5777	5949.5	1685.50	19 561	12.563	39.454
¼	79.325	500.74	6.6104	6008.9	1702.32	19 953	12.625	39.848
⅜	79.718	505.71	6.6432	6068.5	1719.21	20 351	12.688	40.243
½	80.111	510.71	6.6759	6128.5	1736.19	20 755	12.750	40.641
⅝	80.503	515.72	6.7086	6188.7	1753.26	21 165	12.813	41.040
¾	80.896	520.77	6.7413	6249.2	1770.40	21 581	12.875	41.441
⅞	81.289	525.84	6.7741	6310.0	1787.63	22 003	12.938	41.845
26	81.681	530.93	6.8068	6371.2	1804.95	22 432	13.000	42.250

Properties of Tubes and Round Bars (Continued) — **26** inches – **31** inches

For Tubes use differences for A, W, I and V (for volume of wall only), sum for R^2, and direct tabular values for C, S, y and V (for capacity). For Round Bars use all tabular values direct.

Diam. in inches	Circum-ference in inches	Area cross section sq. in.	Per foot length			Moment of inertia	Distance from axis to farthest fiber	Radius of gyration squared
			Surface sq. ft.	Volume cu. in.	Weight, lbs. steel			
D	C	A	S	V	W	I	y	R^2
26	81.681	530.93	6.8068	6371.2	1804.95	22 432	13.000	42.250
⅛	82.074	536.05	6.8395	6432.6	1822.34	22 866	13.063	42.657
¼	82.467	541.19	6.8722	6494.3	1839.82	23 307	13.125	43.066
⅜	82.860	546.35	6.9050	6556.3	1857.39	23 754	13.188	43.478
½	83.252	551.55	6.9377	6618.6	1875.04	24 208	13.250	43.891
⅝	83.645	556.76	6.9704	6681.1	1892.77	24 668	13.313	44.306
¾	84.038	562.00	7.0031	6744.0	1910.58	25 134	13.375	44.723
⅞	84.430	567.27	7.0359	6807.2	1928.48	25 607	13.438	45.142
27	84.823	572.56	7.0686	6870.7	1946.46	26 087	13.500	45.563
⅛	85.216	577.87	7.1013	6934.4	1964.52	26 574	13.563	45.985
¼	85.608	583.21	7.1340	6998.5	1982.67	27 067	13.625	46.410
⅜	86.001	588.57	7.1668	7062.8	2000.90	27 567	13.688	46.837
½	86.394	593.96	7.1995	7127.5	2019.22	28 074	13.750	47.266
⅝	86.786	599.37	7.2322	7192.4	2037.62	28 588	13.813	47.696
¾	87.179	604.81	7.2649	7257.7	2056.10	29 109	13.875	48.129
⅞	87.572	610.27	7.2977	7323.2	2074.66	29 637	13.938	48.563
28	87.965	615.75	7.3304	7389.0	2093.31	30 172	14.000	49.000
⅛	88.357	621.26	7.3631	7455.1	2112.04	30 714	14.063	49.438
¼	88.750	626.80	7.3958	7521.6	2130.86	31 264	14.125	49.879
⅜	89.143	632.36	7.4286	7588.3	2149.76	31 821	14.188	50.321
½	89.535	637.94	7.4613	7655.3	2168.74	32 385	14.250	50.766
⅝	89.928	643.55	7.4940	7722.6	2187.81	32 957	14.313	51.212
¾	90.321	649.18	7.5267	7790.2	2206.95	33 537	14.375	51.660
⅞	90.713	654.84	7.5595	7858.1	2226.19	34 124	14.438	52.110
29	91.106	660.52	7.5922	7926.2	2245.50	34 719	14.500	52.563
⅛	91.499	666.23	7.6249	7994.7	2264.90	35 321	14.563	53.017
¼	91.892	671.96	7.6576	8063.5	2284.39	35 931	14.625	53.473
⅜	92.284	677.71	7.6904	8132.6	2303.95	36 550	14.688	53.931
½	92.677	683.49	7.7231	8201.9	2323.60	37 176	14.750	54.391
⅝	93.070	689.30	7.7558	8271.6	2343.34	37 810	14.813	54.853
¾	93.462	695.13	7.7885	8341.5	2363.15	38 452	14.875	55.316
⅞	93.855	700.98	7.8213	8411.8	2383.05	39 102	14.938	55.782
30	94.248	706.86	7.8540	8482.3	2403.04	39 761	15.000	56.250
⅛	94.640	712.76	7.8867	8553.1	2423.10	40 428	15.063	56.720
¼	95.033	718.69	7.9194	8624.3	2443.25	41 103	15.125	57.191
⅜	95.426	724.64	7.9522	8695.7	2463.49	41 786	15.188	57.665
½	95.819	730.62	7.9849	8767.4	2483.80	42 479	15.250	58.141
⅝	96.211	736.62	8.0176	8839.4	2504.21	43 179	15.313	58.618
¾	96.604	742.64	8.0503	8911.7	2524.69	43 888	15.375	59.098
⅞	96.997	748.69	8.0831	8984.3	2545.26	44 606	15.438	59.579
31	97.389	754.77	8.1158	9057.2	2565.91	45 333	15.500	60.063

Properties of Tubes and Round Bars (Concluded) **31 inches** **36 inches**

For Tubes use differences for *A*, *W*, *I* and *V* (for volume of wall only), sum for R^2, and direct tabular values for *C*, *S*, *y* and *V* (for capacity). For Round Bars use all tabular values direct.

Diam. in inches *D*	Circumference in inches *C*	Area cross section sq. in. *A*	Per foot length: Surface sq. ft. *S*	Per foot length: Volume cu. in. *V*	Per foot length: Weight, lbs. steel *W*	Moment of inertia *I*	Distance from axis to farthest fiber *y*	Radius of gyration squared R^2
31	97.389	754.77	8.1158	9057.2	2565.91	45 333	15.500	60.063
1/8	97.782	760.87	8.1485	9130.4	2586.64	46 069	15.563	60.548
1/4	98.175	766.99	8.1812	9203.9	2607.46	46 813	15.625	61.035
3/8	98.567	773.14	8.2140	9277.7	2628.36	47 567	15.688	61.524
1/2	98.960	779.31	8.2467	9351.7	2649.35	48 329	15.750	62.016
5/8	99.353	785.51	8.2794	9426.1	2670.42	49 101	15.813	62.509
3/4	99.746	791.73	8.3121	9500.8	2691.57	49 882	15.875	63.004
7/8	100.138	797.98	8.3449	9575.7	2712.80	50 672	15.938	63.501
32	100.531	804.25	8.3776	9651.0	2734.12	51 472	16.000	64.000
1/8	100.924	810.54	8.4103	9726.5	2755.52	52 281	16.063	64.501
1/4	101.316	816.86	8.4430	9802.4	2777.01	53 099	16.125	65.004
3/8	101.709	823.21	8.4758	9878.5	2798.58	53 927	16.188	65.509
1/2	102.102	829.58	8.5085	9954.9	2820.23	54 765	16.250	66.016
5/8	102.494	835.97	8.5412	10031.6	2841.97	55 612	16.313	66.524
3/4	102.887	842.39	8.5739	10108.7	2863.78	56 470	16.375	67.035
7/8	103.280	848.83	8.6067	10186.0	2885.69	57 337	16.438	67.548
33	103.673	855.30	8.6394	10263.6	2907.67	58 214	16.500	68.063
1/8	104.065	861.79	8.6721	10341.5	2929.74	59 101	16.563	68.579
1/4	104.458	868.31	8.7048	10419.7	2951.90	59 998	16.625	69.098
3/8	104.851	874.85	8.7376	10498.2	2974.13	60 905	16.688	69.618
1/2	105.243	881.41	8.7703	10577.0	2996.45	61 823	16.750	70.141
5/8	105.636	888.00	8.8030	10656.0	3018.86	62 751	16.813	70.665
3/4	106.029	894.62	8.8357	10735.4	3041.34	63 689	16.875	71.191
7/8	106.421	901.26	8.8685	10815.1	3063.91	64 638	16.938	71.720
34	106.814	907.92	8.9012	10895.0	3086.57	65 597	17.000	72.250
1/8	107.207	914.61	8.9339	10975.3	3109.30	66 567	17.063	72.782
1/4	107.600	921.32	8.9666	11055.9	3132.12	67 548	17.125	73.316
3/8	107.992	928.06	8.9994	11136.7	3155.03	68 539	17.188	73.853
1/2	108.385	934.82	9.0321	11217.8	3178.01	69 542	17.250	74.391
5/8	108.778	941.61	9.0648	11299.3	3201.09	70 555	17.313	74.931
3/4	109.170	948.42	9.0975	11381.0	3224.24	71 580	17.375	75.473
7/8	109.563	955.25	9.1303	11463.0	3247.48	72 615	17.438	76.017
35	109.956	962.11	9.1630	11545.4	3270.80	73 662	17.500	76.563
1/8	110.348	969.00	9.1957	11628.0	3294.20	74 720	17.563	77.110
1/4	110.741	975.91	9.2284	11710.9	3317.69	75 789	17.625	77.660
3/8	111.134	982.84	9.2612	11794.1	3341.26	76 870	17.688	78.212
1/2	111.527	989.80	9.2939	11877.6	3364.92	77 962	17.750	78.766
5/8	111.919	996.78	9.3266	11961.4	3388.66	79 066	17.813	79.321
3/4	112.312	1003.79	9.3593	12045.5	3412.48	80 182	17.875	79.879
7/8	112.705	1010.82	9.3921	12129.8	3436.38	81 309	17.938	80.438
36	113.097	1017.88	9.4248	12214.5	3460.37	82 448	18.000	81.000

THE METRIC SYSTEM

(Extract from tables of equivalents published by the Department of Commerce and Labor, Bureau of Standards.)

The fundamental unit of the metric system is the METER (the unit of length).

From this the units of mass (GRAM) and capacity (LITER) are derived.

All other units are the decimal subdivisions or multiples of these. These three units are simply related, so that for all practical purposes the volume of one kilogram of water (one liter) is equal to one cubic decimeter.

Prefixes	Meaning			Units
Milli-	=one thousandth	$\frac{1}{1000}$	.001	
Centi-	=one hundredth	$\frac{1}{100}$	.01	METER for length
Deci-	=one tenth	$\frac{1}{10}$	.1	
unit	=one		1.	GRAM for mass
Deka-	=ten	$\frac{10}{1}$	10.	
Hecto-	=one hundred	$\frac{100}{1}$	100.	LITER for capacity
Kilo-	=one thousand	$\frac{1000}{1}$	1000.	

The metric terms are formed by combining the words "Meter," "Gram" and "Liter" with the six numerical prefixes.

Length

10 milli-meters (mm)	= 1 centi-meter (cm).
10 centi-meters	= 1 deci-meter (dm).
10 deci-meters	= 1 METER (about 40 inches) (m).
10 meters	= 1 deka-meter (dkm).
10 deka-meters	= 1 hecto-meter (hm).
10 hecto-meters	= 1 kilo-meter (about ⅝ mile) (km).

Mass

10 milli-grams (mg)	= 1 centi-gram (cg).
10 centi-grams	= 1 deci-gram (dg).
10 deci-grams	= 1 GRAM (about 15 grains) (g).
10 grams	= 1 deka-gram (dkg).
10 deka-grams	= 1 hecto-gram (hg).
10 hecto-grams	= 1 kilo-gram (about 2 pounds) (kg).

Capacity

10 milli-liters (ml)	= 1 centi-liter (cl).
10 centi-liters	= 1 deci-liter (dl).
10 deci-liters	= 1 liter (about 1 quart) (l).
10 liters	= 1 deka-liter (dkl).
10 deka-liters	= 1 hecto-liter (about a barrel) (hl).
10 hecto-liters	= 1 kilo-liter (kl).

The square and cubic units are the squares and cubes of the linear units.

The ordinary unit of land area is the Hectare (about 2½ acres).

For ordinary mental comparison it is convenient to know the approximate relations; e.g., 1 meter = 40 inches; 3 decimeters = 1 foot; 1 decimeter = 4 inches; 1 liter = 1 liquid quart; 1 kilogram = 2⅕ pounds; 30 grams = 1 avoirdupois ounce; 1 metric ton = 1 gross ton (see tables).

Equivalents

All lengths, areas and cubic measures in the following tables are derived from the international meter, the legal equivalent being 1 METER = 39.37 INCHES (law of July 28, 1866). In 1893 the United States Office of Standard Weights and Measures was authorized to derive the yard from the meter, using for the purpose the relation legalized in 1866, 1 YARD EQUALS $\frac{3600}{3937}$ METER. The customary weights are likewise referred to the kilogram. (Executive order approved April 5, 1893.) This action fixed the values, inasmuch as the reference standards are as perfect and unalterable as it is possible for human skill to make them.

All capacities are based on the practical equivalent 1 cubic decimeter equals 1 liter. The decimeter is equal to 3.937 inches in accordance with the legal equivalent of the meter given above. The gallon referred to in the tables is the United States gallon of 231 cubic inches. The bushel is the United States bushel of 2150.42 cubic inches. There units must not be confused with the British units of the same name, which differ from those used in the United States. The British gallon is approximately 20 per cent larger, and the British bushel 3 per cent larger, than the corresponding units used in this country.

The customary weights derived from the international kilogram are based on the value 1 avoirdupois pound = 453.5924277 grams. This value is carried out farther than that given in the law, but is in accord with the latter as far as it is there given. The value of the troy pound is based upon the relation just mentioned, and also the equivalent $\frac{5760}{7000}$ avoirdupois pound equals 1 troy pound.

Length

Centimeter	= 0.3937 inch.
Meter	= 3.28 feet.
Meter	= 1.094 yards.
Kilometer	= 0.621 statute mile.
Kilometer	= 0.5396 nautical mile.
Inch	= 2.540 centimeters.
Foot	= 0.305 meter.
Yard	= 0.914 meter.
Statute mile	= 1.61 kilometers.
Nautical mile	= 1.853 kilometers.

Area

Square centimeter	= 0.155 square inch.
Square meter	= 10.76 square feet.
Square meter	= 1.196 square yards.
Hectare	= 2.47 acres.
Square kilometer	= 0.386 square mile.
Square inch	= 6.45 square centimeters.
Square foot	= 0.0929 square meter.
Square yard	= 0.836 square meter.
Acre	= 0.405 hectare.
Square mile	= 2.59 square kilometers.

Volume

Cubic centimeter	= 0.0610 cubic inch.
Cubic meter	= 35.3 cubic feet.
Cubic meter	= 1.308 cubic yards.
Cubic inch	= 16.39 cubic centimeters.
Cubic foot	= 0.0283 cubic meter.
Cubic yard	= 0.765 cubic meter.

Capacity

Milliliter	= 0.0338 U. S. liquid ounce.
Milliliter	= 0.2705 U. S. apothecaries' dram.
Liter	= 1.057 U. S. liquid quarts.
Liter	= 0.2642 U. S. liquid gallon.
Liter	= 0.908 U. S. dry quart.
Dekaliter	= 1.135 U. S. pecks.
Hectoliter	= 2.838 U. S. bushels.
U. S. liquid ounce	= 29.57 milliliters.
U. S. apothecaries' dram	= 3.70 milliliters.
U. S. liquid quart	= 0.946 liter.
U. S. dry quart	= 1.101 liters.
U. S. liquid gallon	= 3.785 liters.
U. S. peck	= 0.881 dekaliter.
U. S. bushel	= 0.3524 hectoliter.

Weight

Gram	= 15.43 grains.
Gram	= 0.772 U. S. apothecaries' scruple.
Gram	= 0.2572 U. S. apothecaries' dram.
Gram	= 0.0353 avoirdupois ounce.
Gram	= 0.03215 troy ounce.
Kilogram	= 2.205 avoirdupois pounds.
Kilogram	= 2.679 troy pounds.
Metric ton	= 0.984 gross or long ton.
Metric ton	= 1.102 short or net tons.
Grain	= 0.0648 gram.
U. S. apothecaries' scruple	= 1.296 grams.
U. S. apothecaries' dram	= 3.89 grams.
Avoirdupois ounce	= 28.35 grams.
Troy ounce	= 31.10 grams.
Avoirdupois pound	= 0.4536 kilogram.
Troy pound	= 0.373 kilogram.
Gross or long ton	= 1.016 metric tons.
Short or net ton	= 0.907 metric ton.

Comparison of Customary and Metric Units from 1 to 10

Lengths

Inches	Millimeters	Inches	Centimeters	Feet	Meters
0.03937	= 1	0.3937	= 1	1	= 0.304801
0.07874	= 2	0.7874	= 2	2	= 0.609601
0.11811	= 3	1	= 2.54001	3	= 0.914402
0.15748	= 4	1.1811	= 3	3.28083	= 1
0.19685	= 5	1.5748	= 4	4	= 1.219202
0.23622	= 6	1.9685	= 5	5	= 1.524003
0.27559	= 7	2	= 5.08001	6	= 1.828804
0.31496	= 8	2.3622	= 6	6.56167	= 2
0.35433	= 9	2.7559	= 7	7	= 2.133604
1	= 25.4001	3	= 7.62002	8	= 2.438405
2	= 50.8001	3.1496	= 8	9	= 2.743205
3	= 76.2002	3.5433	= 9	9.84250	= 3
4	= 101.6002	4	= 10.16002	13.12333	= 4
5	= 127.0003	5	= 12.70003	16.40417	= 5
6	= 152.4003	6	= 15.24003	19.68500	= 6
7	= 177.8004	7	= 17.78004	22.96583	= 7
8	= 203.2004	8	= 20.32004	26.24667	= 8
9	= 228.6005	9	= 22.86005	29.52750	= 9

U. S. yards	Meters	U. S. miles	Kilometers
1	= 0.914402	0.62137	= 1
1.093611	= 1	1	= 1.60935
2	= 1.828804	1.24274	= 2
2.187222	= 2	1.86411	= 3
3	= 2.743205	2	= 3.21869
3.280833	= 3	2.48548	= 4
4	= 3.657607	3	= 4.82804
4.374444	= 4	3.10685	= 5
5	= 4.572009	3.72822	= 6
5.468056	= 5	4	= 6.43739
6	= 5.486411	4.34959	= 7
6.561667	= 6	4.97096	= 8
7	= 6.400813	5	= 8.04674
7.655278	= 7	5.59233	= 9
8	= 7.315215	6	= 9.65608
8.748889	= 8	7	= 11.26543
9	= 8.229616	8	= 12.87478
9.842500	= 9	9	= 14.48412

Comparison of Customary and Metric Units from 1 to 10 (Continued)

Areas

Square inches	Square millimeters	Square inches	Square centimeters	Square feet	Square meters
0.00155 =	1	0.1550 =	1	1	= 0.09290
0.00310 =	2	0.3100 =	2	2	= 0.18581
0.00465 =	3	0.4650 =	3	3	= 0.27871
0.00620 =	4	0.6200 =	4	4	= 0.37161
0.00775 =	5	0.7750 =	5	5	= 0.46452
0.00930 =	6	0.9300 =	6	6	= 0.55742
0.01085 =	7	1	= 6.452	7	= 0.65032
0.01240 =	8	1.0850 =	7	8	= 0.74323
0.01395 =	9	1.2400 =	8	9	= 0.83613
1	= 645.16	1.3950 =	9	10 764 =	1
2	= 1290.33	2	= 12.903	21 528 =	2
3	= 1935.49	3	= 19.355	32 292 =	3
4	= 2580.65	4	= 25.807	43 055 =	4
5	= 3225.81	5	= 32.258	53 819 =	5
6	= 3870.98	6	= 38.710	64 583 =	6
7	= 4516.14	7	= 45.161	75 347 =	7
8	= 5161.30	8	= 51.613	86 111 =	8
9	= 5806.46	9	= 58.065	96 875 =	9

Square yards	Square meters	Square miles	Square kilometers	Acres	Hectares
1	= 0.8361	0.3861 =	1	1	= 0.4047
1.1960 =	1	0.7722 =	2	2	= 0.8094
2	= 1.6723	1	= 2.5900	2.471 =	1
2.3920 =	2	1.1583 =	3	3	= 1.2141
3	= 2.5084	1.5444 =	4	4	= 1.6187
3.5880 =	3	1.9305 =	5	4.942 =	2
4	= 3.3445	2	= 5.1800	5	= 2.0234
4.7839 =	4	2.3166 =	6	6	= 2.4281
5	= 4.1807	2.7027 =	7	7	= 2.8328
5.9799 =	5	3	= 7.7700	7.413 =	3
6	= 5.0168	3.0888 =	8	8	= 3.2375
7	= 5.8529	3.4749 =	9	9	= 3.6422
7.1759 =	6	4	= 10.3600	9.884 =	4
8	= 6.6890	5	= 12.9500	12.355 =	5
8.3719 =	7	6	= 15.5400	14.826 =	6
9	= 7.5252	7	= 18.1300	17.297 =	7
9.5679 =	8	8	= 20.7200	19.768 =	8
10.7639 =	9	9	= 23.3100	22.239 =	9

Comparison of Customary and Metric Units from 1 to 10 (Continued)

Volumes

Cubic inches	Cubic milli-meters	Cubic inches	Cubic centi-meters	Cubic feet	Cubic meters	Cubic yards	Cubic meters
0.000061	= 1	0.0610	= 1	1	= 0.02832	1	= 0.7645
0.000122	= 2	0.1220	= 2	2	= 0.05663	1.3079	= 1
0.000183	= 3	0.1831	= 3	3	= 0.08495	2	= 1.5291
0.000244	= 4	0.2441	= 4	4	= 0.11327	2.6159	= 2
0.000305	= 5	0.3051	= 5	5	= 0.14159	3	= 2.2937
0.000366	= 6	0.3661	= 6	6	= 0.16990	3.9238	= 3
0.000427	= 7	0.4272	= 7	7	= 0.19822	4	= 3.0582
0.000488	= 8	0.4882	= 8	8	= 0.22654	5	= 3.8228
0.000549	= 9	0.5492	= 9	9	= 0.25485	5.2318	= 4
1	= 16 387.2	1	= 16.3872	35.314	= 1	6	= 4.5874
2	= 32 774.3	2	= 32.7743	70.629	= 2	6.5397	= 5
3	= 49 161.5	3	= 49.1615	105.943	= 3	7	= 5.3519
4	= 65 548.6	4	= 65.5486	141.258	= 4	7.8477	= 6
5	= 81 935.8	5	= 81.9358	176.572	= 5	8	= 6.1165
6	= 98 323.0	6	= 98.3230	211.887	= 6	9	= 6.8810
7	= 114 710.1	7	= 114.7101	247.201	= 7	9.1556	= 7
8	= 131 097.3	8	= 131.0973	282.516	= 8	10.4635	= 8
9	= 147 484.5	9	= 147.4845	317.830	= 9	11.7715	= 9

Comparison of Customary and Metric Units from 1 to 10 (Continued)

Capacities

U. S. liquid ounces	Milliliters (cc.)	U. S. apothecaries' drams	Milliliters (cc.)	U. S. apothecaries' scruples	Milliliters (cc.)
0.03381	1	0.2705	1	0.8115	1
0.06763	2	0.5410	2	1	1.2322
0.10144	3	0.8115	3	1.6231	2
0.13526	4	1	3.6967	2	2.4645
0.16907	5	1.0820	4	2.4346	3
0.20288	6	1.3525	5	3	3.6967
0.23670	7	1.6231	6	3.2461	4
0.27051	8	1.8936	7	4	4.9290
0.30432	9	2	7.3934	4.0577	5
1	29.574	2.1641	8	4.8692	6
2	59.147	2.4346	9	5	6.1612
3	88.721	3	11.0901	5.6807	7
4	118.295	4	14.7869	6	7.3934
5	147.869	5	18.4836	6.4923	8
6	177.442	6	22.1803	7	8.6257
7	207.016	7	25.8770	7.3038	9
8	236.590	8	29.5737	8	9.8579
9	266.163	9	33.2704	9	11.0901

U. S. liquid quarts	Liters	U. S. liquid gallons	Liters
1	0.94636	0.26417	1
1.05668	1	9.52834	2
2	1.89272	0.79251	3
2.11336	2	1	3.78543
3	2.83908	1.05668	4
3.17005	3	1.32085	5
4	3.78543	1.58502	6
4.22673	4	1.84919	7
5	4.73179	2	7.57087
5.28341	5	2.11336	8
6	5.67815	2.37753	9
6.34009	6	3	11.35630
7	6.62451	4	15.14174
7.39677	7	5	18.92717
8	7.57088	6	22.71261
8.45345	8	7	26.49804
9	8.51723	8	30.28348
9.51014	9	9	34.06891

Comparison of Customary and Metric Units from 1 to 10 (Continued)

Capacities (Concluded)

U. S. dry quarts	Liters	U. S. pecks	Liters	U. S. pecks	Deka-liters
0.9081	=1	0.11331	= 1	1	=0.8810
1	=1.1012	0.22702	= 2	1.1351	=1
1.8162	=2	0.34053	= 3	2	=1.7620
2	=2.2025	0.45404	= 4	2.2702	=2
2.7242	=3	0.56755	= 5	3	=2.6429
3	=3.3037	0.68106	= 6	3.4053	=3
3.6323	=4	0.79457	= 7	4	=3.5239
4	=4.4049	0.90808	= 8	4.5404	=4
4.5404	=5	1	= 8.80982	5	=4.4049
5	=5.5061	1.02157	= 9	5.6755	=5
5.4485	=6	2	=17.61964	6	=5.2859
6	=6.6074	3	=26.42946	6.8106	=6
6.3565	=7	4	=35.23928	7	=6.1669
7	=7.7086	5	=44.04910	7.9457	=7
7.2646	=8	6	=52.85892	8	=7.0479
8	=8.8098	7	=61.66874	9	=7.9288
8.1727	=9	8	=70.47856	9.0808	=8
9	=9.9110	9	=79.28838	10.2159	=9

U. S. bushels	Hecto-liters	U. S. bushels per acre	Hectoliters per hectare
1	=0.35239	1	=0.87078
2	=0.70479	1.14840	=1
2.83774	=1	2	=1.74156
3	=1.05718	2.29680	=2
4	=1.40957	3	=2.61233
5	=1.76196	3.44519	=3
5.67548	=2	4	=3.48311
6	=2.11436	4.59359	=4
7	=2.46675	5	=4.35389
8	=2.81914	5.74199	=5
8.51323	=3	6	=5.22467
9	=3.17154	6.89039	=6
11.35097	=4	7	=6.09545
14.18871	=5	8	=6.96622
17.02645	=6	8.03879	=7
19.86420	=7	9	=7.83700
22.70194	=8	9.18719	=8
25.53968	=9	10.33558	=9

Comparison of Customary and Metric Units from 1 to 10 (Concluded)

Masses

Grains	Grams	Avoirdupois ounces	Grams	Troy ounces	Grams
1	=0.06480	0.03527=	1	0.03215=	1
2	=0.12960	0.07055=	2	0.06430=	2
3	=0.19440	0.10582=	3	0.09645=	3
4	=0.25920	0.14110=	4	0.12860=	4
5	=0.32399	0.17637=	5	0.16075=	5
6	=0.38879	0.21164=	6	0.19290=	6
7	=0.45359	0.24692=	7	0.22506=	7
8	=0.51839	0.28219=	8	0.25721=	8
9	=0.58319	0.31747=	9	0.28936=	9
15.4324=	1	1	= 28.3495	1	= 31.10348
30.8647=	2	2	= 56.6991	2	= 62.20696
46.2971=	3	3	= 85.0486	3	= 93.31044
61.7294=	4	4	=113.3981	4	=124.41392
77.1618=	5	5	=141.7476	5	=155.51740
92.5941=	6	6	=170.0972	6	=186.62088
108.0265=	7	7	=198.4467	7	=217.72437
123.4589=	8	8	=226.7962	8	=248.82785
138.8912=	9	9	=255.1457	9	=279.93133

Avoirdupois pounds	Kilograms	Troy pounds	Kilograms
1	=0.45359	1	=0.37324
2	=0.90718	2	=0.74648
2.20462=	1	2.67923=	1
3	=1.36078	3	=1.11973
4	=1.81437	4	=1.49297
4.40924=	2	5	=1.86621
5	=2.26796	5.35846=	2
6	=2.72155	6	=2.23945
6.61387=	3	7	=2.61269
7	=3.17515	8	=2.98593
8	=3.62874	8.03769=	3
8.81849=	4	9	=3.35918
9	=4.08233	10.71691=	4
11.02311=	5	13.39614=	5
13.22773=	6	16.07537=	6
15.43236=	7	18.75460=	7
17.63698=	8	21.43383=	8
19.84160=	9	24.11306=	9

Lengths — Hundredths of an Inch to Millimeters

(From 1 to 100 hundredths.)

Hundredths of an inch	0	1	2	3	4
	0	.254	.508	.762	1.016
10	2.540	2.794	3.048	3.302	3.556
20	5.080	5.334	5.588	5.842	6.096
30	7.620	7.874	8.128	8.382	8.636
40	10.160	10.414	10.668	10.922	11.176
50	12.700	12.954	13.208	13.462	13.716
60	15.240	15.494	15.748	16.002	16.256
70	17.780	18.034	18.288	18.542	18.796
80	20.320	20.574	20.828	21.082	21.336
90	22.860	23.114	23.368	23.622	23.876
Hundredths of an inch	**5**	**6**	**7**	**8**	**9**
	1.270	1.524	1.778	2.032	2.286
10	3.810	4.064	4.318	4.572	4.826
20	6.350	6.604	6.858	7.112	7.366
30	8.890	9.144	9.398	9.652	9.906
40	11.430	11.684	11.938	12.192	12.446
50	13.970	14.224	14.478	14.732	14.986
60	16.510	16.764	17.018	17.272	17.526
70	19.050	19.304	19.558	19.812	20.066
80	21.590	21.844	22.098	22.352	22.606
90	24.130	24.384	24.638	24.892	25.146

Lengths — Millimeters to Decimals of an Inch

(From 1 to 100 units.)

Millimeters	0	1	2	3	4
	0	.03937	.07874	.11811	.15748
10	.39370	.43307	.47244	.51181	.55118
20	.78740	.82677	.86614	.90551	.94488
30	1.18110	1.22047	1.25984	1.29921	1.33858
40	1.57480	1.61417	1.65354	1.69291	1.73228
50	1.96850	2.00787	2.04724	2.08661	2.12598
60	2.36220	2.40157	2.44094	2.48031	2.51968
70	2.75590	2.79527	2.83464	2.87401	2.91338
80	3.14960	3.18897	3.22834	3.26771	3.30708
90	3.54330	3.58267	3.62204	3.66141	3.70078
Millimeters	**5**	**6**	**7**	**8**	**9**
	.19685	.23622	.27559	.31496	.35433
10	.59055	.62992	.66929	.70866	.74803
20	.98425	1.02362	1.06299	1.10236	1.14173
30	1.37795	1.41732	1.45669	1.49606	1.53543
40	1.77165	1.81102	1.85039	1.88976	1.92913
50	2.16535	2.20472	2.24409	2.28346	2.32283
60	2.55905	2.59842	2.63779	2.67716	2.71653
70	2.95275	2.99212	3.03149	3.07086	3.11023
80	3.34645	3.38582	3.42519	3.46456	3.50393
90	3.74015	3.77952	3.81889	3.85826	3.89763

Lengths — Inches and Millimeters. — Equivalents of Decimal and Common Fractions of an Inch in Millimeters

(From 1/64 to 1 inch.)

½'s	¼'s	8ths	16ths	32nds	64ths	Milli-meters	Decimals of an inch
					1	= .397	015625
				1	2	= .794	03125
					3	= 1.191	.046875
			1	2	4	= 1.588	.0625
					5	= 1.984	.078125
				3	6	= 2.381	.09375
					7	= 2.778	.109375
		1	2	4	8	= 3.175	.1250
					9	= 3.572	.140625
				5	10	= 3.969	.15625
					11	= 4.366	171875
			3	6	12	= 4.763	.1875
					13	= 5.159	.203125
				7	14	= 5.556	.21875
					15	= 5.953	.234375
	1	2	4	8	16	= 6.350	.2500
					17	= 6.747	.265625
				9	18	= 7.144	.28125
					19	= 7.541	.296875
			5	10	20	= 7.938	.3125
					21	= 8.334	.328125
				11	22	= 8.731	.34375
					23	= 9.128	.359375
		3	6	12	24	= 9.525	.3750
					25	= 9.922	.390625
				13	26	=10.319	.40625
					27	=10.716	.421875
			7	14	28	=11.113	.4375
					29	=11.509	453125
				15	30	=11.906	.46875
					31	=12.303	.484375
1	2	4	8	16	32	=12.700	.5

1 inch = .02540 meter. 2 inches = .05080 meter. 3 inches = .07620 meter.	4 inches = .10160 meter. 5 inches = .12700 meter. 6 inches = .15240 meter.

Lengths — Inches and Millimeters. — Equivalents of Decimal and Common Fractions of an Inch in Millimeters (Concluded)

(From 1/64 to 1 inch.)

Inch	1/2's	1/4's	8ths	16ths	32nds	64ths	Milli-meters	Decimals of an inch
....	....	....	....	....	....	33	=13.097	.515625
....	....	....	....	....	17	34	=13.494	.53125
....	....	....	....	....	....	35	=13.891	.546875
....	....	....	....	9	18	36	=14.288	.5625
....	....	....	....	....	....	37	=14.684	.578125
....	....	....	....	....	19	38	=15.081	.59375
....	....	....	....	....	....	39	=15.478	.609375
....	....	....	5	10	20	40	=15.875	.625
....	....	....	....	....	....	41	=16.272	.640625
....	....	....	....	....	21	42	=16.669	.65625
....	....	....	....	....	....	43	=17.066	.671875
....	....	....	....	11	22	44	=17.463	.6875
....	....	....	....	....	....	45	=17.859	.703125
....	....	....	....	....	23	46	=18.256	.71875
....	....	....	....	....	....	47	=18.653	.734375
....	....	3	6	12	24	48	=19.050	.75
....	....	....	....	....	....	49	=19.447	.765625
....	....	....	....	....	25	50	=19.844	.78125
....	....	....	....	....	....	51	=20.241	.796875
....	....	....	....	13	26	52	=20.638	.8125
....	....	....	....	....	....	53	=21.034	.828125
....	....	....	....	....	27	54	=21.431	.84375
....	....	....	....	....	....	55	=21.828	.859375
....	....	....	7	14	28	56	=22.225	.875
....	....	....	....	....	....	57	=22.622	.890625
....	....	....	....	....	29	58	=23.019	.90625
....	....	....	....	....	....	59	=23.416	.921875
....	....	....	....	15	30	60	=23.813	.9375
....	....	....	....	....	....	61	=24.209	.953125
....	....	....	....	....	31	62	=24.606	.96875
....	....	....	....	....	....	63	=25.003	.984375
1	2	4	8	16	32	64	=25.400	1.000

7 inches = .17780 meter.	10 inches = .25400 meter.
8 inches = .20320 meter.	11 inches = .27940 meter.
9 inches = .22860 meter.	12 inches = .30480 meter.

Comparison of the Various Tons and Pounds in Use in the United States

(From 1 to 10 units.)

Long tons	Short tons	Metric tons	Kilograms	Avoirdupois pounds	Troy pounds
.00036735	.00041143	.00037324	.37324	.822857	1
.00044643	.00050000	.00045359	.45359	1	1.21528
.00073469	.00082286	.00074648	.74648	1.64571	2
.00089286	.00100000	.00090718	.90718	2	2.43056
.00098421	.00110231	.00100000	1	2.20462	2.67923
.00110204	.00123429	.00111973	1.11973	2.46857	3
.00133929	.00150000	.00136078	1.36078	3	3.64583
.00146939	.00164571	.00149297	1.49297	3.29143	4
.00178571	.00200000	.00181437	1.81437	4	4.86111
.00183673	.00205714	.00186621	1.86621	4.11429	5
.00196841	.00220462	.00200000	2	4.40924	5.35846
.00220408	.00246857	.00223945	2.23945	4.93714	6
.00223214	.00250000	.00226796	2.26796	5	6.07639
.00257143	.00288000	.00261269	2.61269	5.76000	7
.00267857	.00300000	.00272155	2.72155	6	7.29167
.00293878	.00329143	.00298593	2.98593	6.58286	8
.00295262	.00330693	.00300000	3	6.61387	8.03769
.00312500	.00350000	.00317515	3.17515	7	8.50694
.00330612	.00370286	.00335918	3.35918	7.40571	9
.00357143	.00400000	.00362874	3.62874	8	9.72222
.00393683	.00440924	.00400000	4	8.81849	10.71691
.00401786	.00450000	.00408233	4.08233	9	10.93750
.00492103	.00551156	.00500000	5	11.0231	13.39614
.00590524	.00661387	.00600000	6	13.2277	16.07537
.00688944	.00771618	.00700000	7	15.4324	18.75460
.00787365	.00881849	.00800000	8	17.6370	21.43383
.00885786	.00992080	.00900000	9	19.8416	24.11306
.89287	1	.90718	907.18	2 000.00	2 430.56
.98421	1.10231	1	1 000.00	2 204.62	2 679.23
1	1.12000	1.01605	1 016.05	2 240.00	2 722.22
1.78571	2	1.81437	1 814.37	4 000.00	4 861.11
1.96841	2.20462	2	2 000.00	4 409.24	5 358.46
2	2.24000	2.03209	2 032.09	4 480.00	5 444.44
2.67857	3	2.72155	2 721.55	6 000.00	7 291.67
2.95262	3.30693	3	3 000.00	6 613.87	8 037.69
3	3.36000	3.04814	3 048.14	6 720.00	8 166.67
3.57143	4	3.62874	3 628.74	8 000.00	9 722.22
3.93683	4.40924	4	4 000.00	8 818.49	10 716.91
4	4.48000	4.06419	4 064.19	8 960.00	10 888.89
4.46429	5	4.53592	4 535.92	10 000.00	12 152.78
4.92103	5.51156	5	5 000.00	11 023.11	13 396.14
5	5.60000	5.08024	5 080.24	11 200.00	13 611.11
5.35714	6	5.44311	5 443.11	12 000.00	14 583.33
5.90524	6.61387	6	6 000.00	13 227.73	16 075.37
6	6.72000	6.09628	6 096.28	13 440.00	16 333.33
6.25000	7	6.35029	6 350.29	14 000.00	17 013.89
6.88944	7.71618	7	7 000.00	15 432.36	18 754.60
7	7.84000	7.11232	7 112.32	15 680.00	19 055.56
7.14286	8	7.25748	7 257.48	16 000.00	19 444.44
7.87365	8.81849	8	8 000.00	17 636.98	21 433.83
8	8.96000	8.12838	8 128.38	17 920.00	21 777.78
8.03571	9	8.16466	8 164.66	18 000.00	21 875.00
8.85786	9.92080	9	9 000.00	19 841.60	24 113.06
9	10.08000	9.14442	9 144.42	20 160.00	24 500.00

Centigrade to Fahrenheit

Temperature Fahrenheit = $\frac{9}{5}$ Temperature Centigrade + 32

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
−273.00	−460.7	Zero	+32.0	46	114.8	470	878	930	1706
−260.00	−436.0	+1	+33.8	47	116.6	480	896	940	1724
−250.00	−418.0	2	35.6	48	118.4	490	914	950	1742
−240.00	−400.0	3	37.4	49	120.2	500	932	960	1760
−230.00	−382.0	4	39.2	50	122.0	510	950	970	1778
−220.00	−364.0	5	41.0	60	140.0	520	968	980	1796
−210.00	−346.0	6	42.8	70	158.0	530	986	990	1814
−200.00	−328.0	7	44.6	80	176.0	540	1004	1000	1832
−190.00	−310.0	8	46.4	90	194.0	550	1022	1010	1850
−180.00	−292.0	9	48.2	100	212.0	560	1040	1020	1868
−170.00	−274.0	10	50.0	110	230.0	570	1058	1030	1886
−160.00	−256.0	11	51.8	120	248.0	580	1076	1040	1904
−150.00	−238.0	12	53.6	130	266.0	590	1094	1050	1922
−140.00	−220.0	13	55.4	140	284.0	600	1112	1060	1940
−130.00	−202.0	14	57.2	150	302.0	610	1130	1070	1958
−120.00	−184.0	15	59.0	160	320.0	620	1148	1080	1976
−110.00	−166.0	16	60.8	170	338.0	630	1166	1090	1994
−100.00	−148.0	17	62.6	180	356.0	640	1184	1100	2012
− 90.00	−130.0	18	64.4	190	374.0	650	1202	1110	2030
− 80.00	−112.0	19	66.2	200	392.0	660	1220	1120	2048
− 70.00	− 94.0	20	68.0	210	410.0	670	1238	1130	2066
− 60.00	− 76.0	21	69.8	220	428.0	680	1256	1140	2084
− 50.00	− 58.0	22	71.6	230	446.0	690	1274	1150	2102
− 40.00	− 40.0	23	73.4	240	464.0	700	1292	1160	2120
− 30.00	− 22.0	24	75.2	250	482.0	710	1310	1170	2138
− 20.00	− 4.0	25	77.0	260	500.0	720	1328	1180	2156
− 19.00	− 2.2	26	78.8	270	518.0	730	1346	1190	2174
− 18.00	− 0.4	27	80.6	280	536.0	740	1364	1200	2192
− 17.77	Zero	28	82.4	290	554.0	750	1382	1210	2210
− 17.00	+ 1.4	29	84.2	300	572.0	760	1400	1220	2228
− 16.00	+ 3.2	30	86.0	310	590.0	770	1418	1230	2246
− 15.00	+ 5.0	31	87.8	320	608.0	780	1436	1240	2264
− 14.00	+ 6.8	32	89.6	330	626	790	1454	1250	2282
− 13.00	+ 8.6	33	91.4	340	644	800	1472	1260	2300
− 12.00	+ 10.4	34	93.2	350	662	810	1490	1270	2318
− 11.00	+ 12.2	35	95.0	360	680	820	1508	1280	2336
− 10.00	+ 14.0	36	96.8	370	698	830	1526	1290	2354
− 9.00	+ 15.8	37	98.6	380	716	840	1544	1300	2372
− 8 00	+ 17.6	38	100.4	390	734	850	1562	1310	2390
− 7.00	+ 19.4	39	102.2	400	752	860	1580	1320	2408
− 6.00	+ 21.2	40	104.0	410	770	870	1598	1330	2426
− 5.00	+ 23.0	41	105.8	420	788	880	1616	1340	2444
− 4.00	+ 24.8	42	107.6	430	806	890	1634	1350	2462
− 3.00	+ 26.6	43	109.4	440	824	900	1652	1360	2480
− 2.00	+ 28.4	44	111.2	450	842	910	1670	1370	2498
− 1.00	+ 30.2	45	113.0	460	860	920	1688	1380	2516

Centigrade to Fahrenheit (Concluded)

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
1390	2534	1550	2822	1710	3110	1870	3398	2030	3686
1400	2552	1560	2840	1720	3128	1880	3416	2040	3704
1410	2570	1570	2858	1730	3146	1890	3434	2050	3722
1420	2588	1580	2876	1740	3164	1900	3452	2060	3740
1430	2606	1590	2894	1750	3182	1910	3470	2070	3758
1440	2624	1600	2912	1760	3200	1920	3488	2080	3776
1450	2642	1610	2930	1770	3218	1930	3506	2090	3794
1460	2660	1620	2948	1780	3236	1940	3524	2100	3812
1470	2678	1630	2966	1790	3254	1950	3542	2110	3830
1480	2696	1640	2984	1800	3272	1960	3560	2120	3848
1490	2714	1650	3002	1810	3290	1970	3578	2130	3866
1500	2732	1660	3020	1820	3308	1980	3596	2140	3884
1510	2750	1670	3038	1830	3326	1990	3614	2150	3902
1520	2768	1680	3056	1840	3344	2000	3632	2160	3920
1530	2786	1690	3074	1850	3362	2010	3650	2180	3956
1540	2804	1700	3092	1860	3380	2020	3668	2200	3992

Fahrenheit to Centigrade

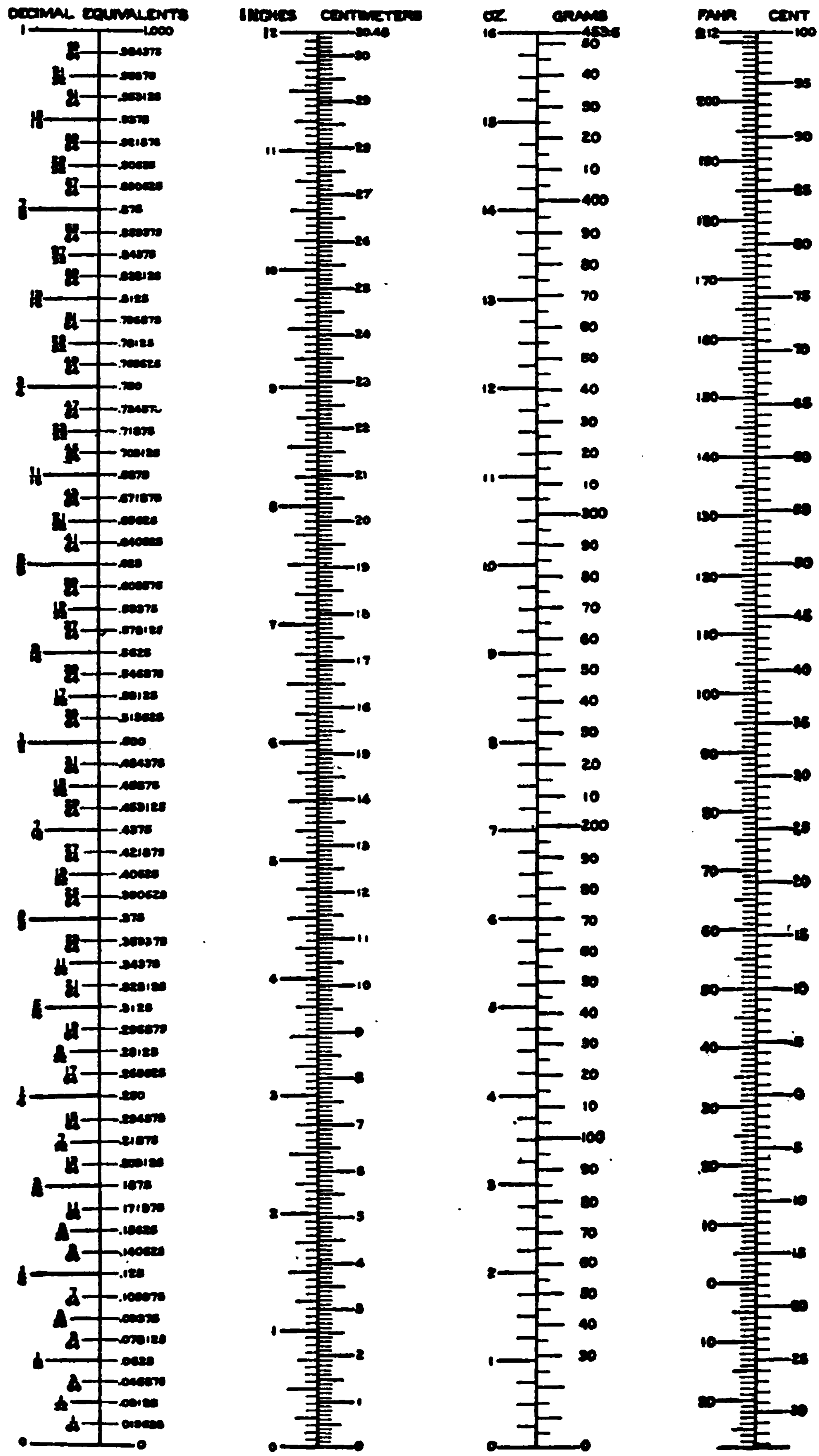
Temperature Centigrade $= \frac{5}{9}$ (Temperature Fahrenheit $- 32$)

Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.
−5	−20.55	11	−11.66	27	−2.77	43	6.11	59	15.00
−4	−20.00	12	−11.11	28	−2.22	44	6.66	60	15.55
−3	−19.44	13	−10.55	29	−1.66	45	7.22	61	16.11
−2	−18.88	14	−10.00	30	−1.11	46	7.77	62	16.66
−1	−18.33	15	− 9.44	31	− .55	47	8.33	63	17.22
Zero	−17.77	16	− 8.88	32	Zero	48	8.88	64	17.77
+1	−17.22	17	− 8.33	33	+ .55	49	9.44	65	18.33
2	−16.66	18	− 7.77	34	1.11	50	10.00	66	18.88
3	−16.11	19	− 7.22	35	1.66	51	10.55	67	19.44
4	−15.55	20	− 6.66	36	2.22	52	11.11	68	20.00
5	−15.00	21	− 6.11	37	2.77	53	11.66	69	20.55
6	−14.44	22	− 5.55	38	3.33	54	12.22	70	21.11
7	−13.88	23	− 5.00	39	3.88	55	12.77	71	21.66
8	−13.33	24	− 4.44	40	4.44	56	13.33	72	22.22
9	−12.77	25	− 3.88	41	5.00	57	13.88	73	22.77
10	−12.22	26	− 3.33	42	5.55	58	14.44	74	23.33

Fahrenheit to Centigrade (Concluded)

Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.
75	23.88	121	49.44	167	75.00	213	100.55	259	126.11
76	24.44	122	50.00	168	75.55	214	101.11	260	126.66
77	25.00	123	50.55	169	76.11	215	101.66	261	127.22
78	25.55	124	51.11	170	76.66	216	102.22	262	127.77
79	26.11	125	51.66	171	77.22	217	102.77	263	128.33
80	26.66	126	52.22	172	77.77	218	103.33	264	128.88
81	27.22	127	52.77	173	78.33	219	103.88	265	129.44
82	27.77	128	53.33	174	78.88	220	104.44	266	130.00
83	28.33	129	53.88	175	79.44	221	105.00	267	130.55
84	28.88	130	54.44	176	80.00	222	105.55	268	131.11
85	29.44	131	55.00	177	80.55	223	106.11	269	131.66
86	30.00	132	55.55	178	81.11	224	106.66	270	132.22
87	30.55	133	56.11	179	81.66	225	107.22	271	132.77
88	31.11	134	56.66	180	82.22	226	107.77	272	133.33
89	31.66	135	57.22	181	82.77	227	108.33	273	133.88
90	32.22	136	57.77	182	83.33	228	108.88	274	134.44
91	32.77	137	58.33	183	83.88	229	109.44	275	135.00
92	33.33	138	58.88	184	84.44	230	110.00	276	135.55
93	33.88	139	59.44	185	85.00	231	110.55	277	136.11
94	34.44	140	60.00	186	85.55	232	111.11	278	136.66
95	35.00	141	60.55	187	86.11	233	111.66	279	137.22
96	35.55	142	61.11	188	86.66	234	112.22	280	137.77
97	36.11	143	61.66	189	87.22	235	112.77	281	138.33
98	36.66	144	62.22	190	87.77	236	113.33	282	138.88
99	37.22	145	62.77	191	88.33	237	113.88	283	139.44
100	37.77	146	63.33	192	88.88	238	114.44	284	140.00
101	38.33	147	63.88	193	89.44	239	115.00	285	140.55
102	38.88	148	64.44	194	90.00	240	115.55	286	141.11
103	39.44	149	65.00	195	90.55	241	116.11	287	141.66
104	40.00	150	65.55	196	91.11	242	116.66	288	142.22
105	40.55	151	66.11	197	91.66	243	117.22	289	142.77
106	41.11	152	66.66	198	92.22	244	117.77	290	143.33
107	41.66	153	67.22	199	92.77	245	118.33	291	143.88
108	42.22	154	67.77	200	93.33	246	118.88	292	144.44
109	42.77	155	68.33	201	93.88	247	119.44	293	145.00
110	43.33	156	68.88	202	94.44	248	120.00	294	145.55
111	43.88	157	69.44	203	95.00	249	120.55	295	146.11
112	44.44	158	70.00	204	95.55	250	121.11	296	146.66
113	45.00	159	70.55	205	96.11	251	121.66	297	147.22
114	45.55	160	71.11	206	96.66	252	122.22	298	147.77
115	46.11	161	71.66	207	97.22	253	122.77	299	148.33
116	46.66	162	72.22	208	97.77	254	123.33	300	148.88
117	47.22	163	72.77	209	98.33	255	123.88	400	204.44
118	47.77	164	73.33	210	98.88	256	124.44	600	315.55
119	48.33	165	73.88	211	99.44	257	125.00	800	426.66
120	48.88	166	74.44	212	100.00	258	125.55	1000	537.77

Conversion Chart for Lengths, Weights and Temperatures



GLOSSARY OF TERMS USED IN THE PIPE AND FITTING TRADE

ABBREVIATIONS

A.I. = All iron (use limited to valves and cocks).
B.D. = Brass disc (use limited to valves).
Bd. = Beaded (use limited to malleable fittings).
B.F. = (1) Blank flange. (2) Blind flange.
B.J. = (1) Ball joint. (2) Brass jacket. (3) Bump joint.
B. & L. = Ball and lever (use limited to valves).
B.L. = Bill of lading.
B.M. = Brass mounted.
B.O.C. = Back outlet central (use limited to fittings).
B.O.E. = Back outlet eccentric (use limited to fittings).
B.P. = (1) Brass plug (use limited to cocks). (2) By-pass (use limited to valves).
Br. = Brass.
B. & S. = Bell and spigot.
B.W. = (1) Butt weld (use limited to pipe). (2) Brass washer (use limited to cocks).
C.D. = Copper disc (use limited to valves).
C. & F. = Cost and freight.
C.I. = Cast iron.
C.I.F. = Cost, insurance and freight.
C.J. = Converse joint.
C.L. = (1) Carload lots. (2) Center line. (3) Cut lengths.
C.P. = Close pattern (use limited to return bends).
C.S. = Countersunk.
D.S. = (1) Double screen (use limited to well points). (2) Double sweep (use limited to tees).
D.W. = Drive well (use limited to drive well points or supplies).
E.A. = Ends annealed (use limited to pipes and tubes).
E. to E. = End to end.
Ex. Hvy. = Extra heavy.
F.A.S. = Free alongside steamer.
F. & D. = Faced and drilled.
F.E. = Flanged ends.
F. to F. = Face to face.
F.H. = Flat head (use limited to cylinders and cocks).
F.O. = Faced only.
f.o.b. = Free on board.
F.O.R. = Free on rails.

F.P. = Fire plug.
F. & R. = Feed and return (use limited to radiators).
F.W. = Full or card weight pipe.
G. & D. = Galvanized and dipped.
H.D.M. = High duty metal (use limited to valves).
H.E. = Hub end.
I.B. = Iron body (use limited to valves).
I.D. = Inside diameter.
I.P. = Briggs' Standard Threads (poor usage).
J.D. = Jenkins disc (use limited to valves).
K.J. = Kimberley joint.
L. = Elbow.
L.C.L. = Less carload lots.
L.H. = (1) Left hand. (2) Lever handle (use limited to cocks).
L.R. = Long radius.
L.S. = (1) Lock shield (use limited to valves and cocks). (2) Long sweep (use limited to fittings).
L.W. = Lap weld.
Mall. = Malleable.
M. & F. = Male and female.
M.I. = Malleable iron.
M.J. = Matheson joint.
m.m. = Millimeter.
M.M.A. = Master Mechanics Association.
M.P. = (1) Medium pattern (use limited to return bends). (2) Medium pressure.
M.S. = Medium sweep (use limited to fittings).
M.S.F.Std. = Master Steam Fitters' standard.
N.P. = Nickel plated (use limited to valves).
N.P.A.O. = Nickel plated all over (use limited to valves).
N.P.T. = Nickel plated trimmings (use limited to radiator valves).
N.R.S. = Nonrising stem (use limited to valves).
O.D. = Outside diameter.
O.H.S. = Open hearth steel.
O.P. = Open pattern (use limited to return bends).
O.S. & Y. = Outside screw and yoke (use limited to valves).
P.C. = Pump column.
P.E. = Plain end.
P.E.N.R. = Plain end not reamed.
P.E.R. = Plain end reamed (use limited to nipples).
P.F. = Plain face.
Pl. = Plain (use limited to fittings).
P. & R. = Plugged and reamed = R. and D.
Q.O. = Quick opening (use limited to valves)
R.B. = Rough body (use limited to valves).
R. & D. = Reamed and drifted = P. & R.
R.H. = Right hand.
R. & L. = Right and left.

S.C. = Service clamp.
S.E. = Screwed ends.
S.O. = { (1) Side outlet (use limited to fittings). (2) Single opening (use limited to radiators).
Sq. H. = Square head.
S. & S. = Screw and socket = T. & C.
S.S. = { (1) Single screened (use limited to well points). (2) Single sweep (use limited to tees).
Std. = Standard.
T. = Tee.
T. & C. = Threads and couplings = S. & S.
T. & G. = Tongue and groove — not understood as male and female.
T.H. = Tee handle (use limited to cocks).
T. no C. = Threads no couplings.
W.I. = Wrought iron.
W.W. = Wood wheel (use limited to valves).
X.H. = Extra heavy.
X.S. = Extra strong.
X.X.H. = Double extra heavy.
X.X.S. = Double extra strong.
Y. = Wye.
Y.T. = Yoke top (use limited to valves).

DEFINITIONS

(Definitions marked * are taken from Hawkins' Mechanical Dictionary.)

A

Ammonia Cock Thread. — Ammonia cock thread is usually larger and has more taper than Briggs' Standard thread. It lacks uniformity and is made to suit customers' requirements.

Ammonia Fitting. — A fitting whose material is especially homogeneous, which usually has its mouth countersunk and both the mouth and thread tinned.

Ammonia Joint. — All joints should be made of wrought iron or steel, as ammonia attacks and eats away copper and its alloys, brass and gun-metal. In consequence of the penetrating nature of ammonia, all flanges should be screwed and then soldered on the pipes. Lead washers should be used for gaskets on all flange joints. Lead or white metal packing must also be used for all valves.*

Angle Gate Valve. — A gate valve with an elbow cast on one end integral with body.

Angle Valve. — A stop-valve whose outlet is at right angles to its inlet branch, thus combining in itself a valve and an elbow. It must not be confused with angle gate valve.

Angus Smith Composition. — A protective coating for valves, fittings, and pipe used for underground work. It is composed of coal tar, tallow, rosin and quicklime and must be applied hot.

Annealed End Tube. — A tube whose ends have been annealed. For annealing to be effective, it is necessary to heat above the critical temperature, and this is higher as the carbon contents are less, so that with the soft steel of which pipe and tubes are made, annealing must be done at a high heat, 1750 to 1800 degrees Fahrenheit, which is a bright orange in shop daylight. The piece may be allowed to cool in the air after being thoroughly heated to this temperature.

Armstrong Joint. — Designed by Sir W. Armstrong. It is a two bolt, flanged or lugged connection for high pressures. The ends of the pipes are peculiarly formed to properly hold a gutta-percha ring. It was originally made in cast iron pipe. The two bolt feature has much to commend it. There are various substitutes for this old, high-class joint; the commonest employ rubber in place of gutta-percha; others employ more bolts in the endeavor to cheapen.

Artesian Joint. — See Cressed Artesian Joint.

Asphalted. — Coated with asphalt literally, but usually some of the special compositions such as California Oil (which has an asphaltic base), coal tar, mineral wax or Gilsonite or Elaterite are added to give the right consistency to suit the average temperature which prevails when the coating is used.

Attemperator. — A coil of pipe, sometimes working on a swivel or hinge, through which refrigerated brine, or other liquor, is passed. Used to cool vessels containing warm liquids, such as fermenting vats.*

B

Back Outlet Central. — Meaning that such outlet is placed centrally or at mid length. (Use limited to fittings.)

Back Outlet Eccentric. — Meaning that back outlet of tee, elbow, etc., is not placed at center. (Use limited to fittings.)

Back Outlet Ell. — An ell with an outlet in the same plane as the run and on the outside of the curve.

Back Pressure Valve. — A valve that usually is made like a low pressure safety valve but capable of being opened independently of the pressure, thereby giving free exhaust. They are usually employed on non-condensing engines when it is desired to use all or part of the exhaust steam for heating, etc. The back pressure maintained by them is usually between one and ten pounds.

Balling. — Nearly the same as peening.

Ball Joint. — A flexible joint made in the shape of a ball or sphere. Many forms of joint employ such spherical surfaces.

Bar. — See Sinker and Water Bar.

Barrel. — See Working Barrel.

Bead. — When applied to fittings means the slight reinforcing ring on the end. A circular molding.

Beaded Tube. — The ends of boiler tubes, after being expanded, are beaded or rounded with a beading tool, just as rivet heads are finished with a die or snap. The process is termed beading.*

Beading. — The name given to the slight flanging of the end of a boiler tube over a tube sheet, or of the pipe, over a peened flange.

Bell. — (1) In pipe fitting, the recessed or enlarged female end of a pipe into which the male end of the next pipe fits; also called hub.

(2) In plumbing, the expanded female portion of a wiped joint.*

Bell and Spigot Joint. — (1) The usual term for the joint in cast iron pipe. Each piece is made with an enlarged diameter or bell at one end into which the plain or spigot end of another piece is inserted when laying. The joint is then made tight by cement, oakum, lead, rubber, or other suitable substance which is driven in or calked into the bell and around the spigot. When a similar joint is made in wrought pipe by means of a cast bell (or Hub) it is at times called hub and spigot joint (poor usage). Matheson Joint is the name applied to a similar joint in wrought pipe which has the bell formed of the pipe.

(2) Applied to fittings or valves, means that one end of the run is a "bell," and the other end is a "spigot," similar to those used on regular cast iron pipe.

Bell Mouthed. — A term used to signify the open end of a vessel or pipe when it expands or spreads out with an increasing diameter, thus resembling a bell. Also called trumpet mouthed.*

Bend. — (1) A curved length of pipe struck to a larger radius than the elbow.

(2) Pipe bent to 45, 90 or 180 degrees is often specified as 1/8, 1/4 or 1/2 bends.

(3) A slight bend is often called a spring. (Poor usage.)

See Close Return, Cross Over, Double, Eighth, Goose Neck, Open Return, Pipe, Return, and Y Bend.

Bibb. — A cock or valve with bent outlet; strictly the bent outlet.

Blank Flange. — (1) A flange that is not drilled but which is otherwise complete.

(2) At times used to signify a blind flange (this is poor usage). Compare blind flange.

(3) At times used to signify a pipe flange that is not threaded, but which is otherwise complete (this is bad usage).

Blanking Flange. — A blind flange, which see (poor usage).

Bleeder. — A small cock or valve to draw off water of condensation from a range of piping.*

Blind Flange. — (1) A flange used to close the end of a pipe. It produces a blind end which is also called a dead end.

(2) It is at times used erroneously to designate a blank flange.

(3) Compare blanking flange.

Block Joint. — A joint used by plumbers in which an inserted joint is combined with a wide flange; used for wiped joints on heavy vertical pipes.*

Boiler Flange. — See Saddle Flange.

Boiler Thimble. — A ring placed between a boiler tube and the tube sheet or header. The term is more often used in connection with locomotive and marine than stationary boilers. (Poor usage.)

Boiler Tube. — One of the tubes by which heat from the furnace is diffused through the water in a steam boiler. The tubes may contain water and be surrounded by the furnace gases as in a water tube boiler or they may act as flues and be surrounded by water as in a tubular boiler. The usual sizes of boiler tubes are 2 to 4 inches.

Bonnet. (1) A cover used to guide and enclose the tail end of a valve spindle.

(2) A cap over the end of a pipe. (Poor usage.)

Bowl. — See Bell.

Box. — See Service and Valve Box.

Box Coil. — An arrangement of heating pipes made up in the form of a rectangular box.

Boyle Union. — Essentially a tongue and groove flange connection in which the tongue is a separate piece placed between two grooved flanges. Usually the groove extends to the threads so that the gasket material seals that point and permits use of flanges that are not screwed very tight.

Bracket Coil. — A heating pipe usually one or two pipes wide, supported by hooks or expansion plates.

Bracket Valve. — A stop-valve with a bracket cast upon its body, so that it may serve as an anchorage or support for the piping which it controls.*

Branch. — The outlet or inlet of a fitting not in line with the run but which may make any angle. See H and Y Branch.

Branch Ell. — (1) Used to designate an elbow having a back outlet in line with one of the outlets of the run. It is also at times called a heel outlet elbow.

(2) Incorrectly used to designate side outlet or back outlet elbow.

Branch Pipe. — A very general term used to signify a pipe either cast or wrought, that is equipped with one or more branches. Many such pipes are used so frequently that they have acquired common names such as tees, crosses, side or back outlet elbows, manifolds, double branch elbows, etc.

The term branch pipe is generally restricted to such as do not conform to usual dimensions.

Branch Tee.—Header.—A tee having many side branches. See Manifold.

Brass Mounted. — When used to describe a globe, angle, or cross valve, it usually means that the valve has a brass bonnet, stem, seat, ring and disc. When used to describe gate valves, usually means brass stem, seat, ring and wedge or disc ring.

Brazed. — Connected by hard solder which usually is copper and zinc — half and half. Such solder requires a full red heat and is commonly used with Borax flux.

Breeches Pipe. — A Y-shaped pipe used for many purposes, especially in locomotives, leading the exhaust from the two cylinders to the blast nozzle.*

Brick Arch Tube. — One of a series of curved iron tubes, used to support the fire-box arch in certain locomotives, also providing increased heating surface and promoting circulation.*

Briggs' Standard. — A list of pipe sizes, thicknesses, threads, etc., compiled by Robert Briggs about 1862 and subsequently adopted as a standard.

Bucket. — The piston of a well pump. It always contains a valve. It is connected to and operated by the sucker rods.

Bull Head Tee. — A tee whose branch is larger than the run.

Bumped. — Convex when applied to cylinder heads.

Bumped Joint. — One having the end of one pipe so expanded that the end of another may be driven in until the rivet holes register. By slightly tapering both ends it is practical to increase the ease of erection and lessen the calking required.

Bushing. — A pipe fitting for the purpose of connecting a pipe with a fitting of larger size, being a hollow plug with internal and external threads to suit the different diameters.* See Flush Bushing.

Butted and Strapped Joint. — A joint where the ends of two pieces of pipe are united by a sleeve and riveted thereto. The strap may be inside or outside and may be single or double riveted.

Butterfly. — (1) The name applied to certain valves made after the design of a damper in a stove pipe.

(2) In pumps this term signifies a double clack valve whose flaps work on a diametral hinge, like the wings of a butterfly.

Butt-weld. — Welded along a seam that is butted and not scarfed or lapped.

By-Pass. — A small passage to permit equalizing the pressure on the two sides of a large valve so that it may be readily opened (or closed).

By-Pass Valve. — A small pilot valve used in connection with a larger valve to equalize the pressure on both sides of the disc of the larger valve before the larger valve is opened.

C

Caliber. — An expression which is often used to mean the inner diameter or bore.

Calking. — (1) In iron working, the calking consists of striking a chisel, or calking tool with a hammer, making a slight indentation along the seam. The effect of this is to force the edge of one plate hard against the other, and thus fill up any slight crevice between the plates which the rivets failed to close.*

(2) The term is used in connection with lead joints or bell and spigot joints in which case the lead is calked.

Calking Recess. — A counterbore or recess in the back of the flange into which lead may be calked for water, or copper for steam.

Calking Tool. — Calking Iron. — A blunt ended chisel used in calking.

Cap. — A fitting that goes over the end of a pipe to close it, producing a dead end.

Card Weight Pipe. — A term used to designate Standard or Full Weight Pipe, which is the Briggs' Standard thickness of pipe.

Casing. — A term applied to pipe when used to case an oil or gas well. It is usually characterized by light weight and fine threads.

Casing Dog. — In boring, a fishing instrument provided with serrated pieces or dogs sliding on a wedge, to grip severed casing.*

Casing Elevator. — A well-boring device consisting of two semi-circular clamps with a chain-link on either, which are hinged together at one end, and secured by a latch at the other. This affords a quickly applied and released attachment for casing to the lifting tackle.*

Casing Fitting. — A fitting threaded with a casing thread.

Casing Head. — (1) A fitting used at top of casing of a well to separate oil and gas, to allow pumping, and cleaning out well, etc. There are many forms.

(2) In well-boring, a heavy mass of iron screwed into the top of a string of casing to take the blows produced by driving the pipe home.*

Casing Shoe. — In well-boring, a ring or ferrule of hard steel with a sharp edge, screwed or shrunk on to the bottom of a string of casing, to cut its way through the formation as the casing is forced down.*

Chain Tongs. — A pipe-fitter's tool; a lever with a serrated end provided with a chain to enlace the pipe. The chain is wrapped around the pipe to hold the lever in place, and the teeth on the end of the latter grip into the pipe, thus affording a powerful leverage to screw or unscrew the joints.*

Chamfer. — To cut at an angle or bevel.

Chasing. — A term that designates the operation of cutting a thread in a lathe, either with hand tools or by power feed. A single cutting point is usually employed, but some mechanics finish by use of a comb or chaser. Pipe threads are seldom chased but are usually cut by taps, dies, etc.

Check. — (1) To prevent flow except in one direction — applied to valves.

(2) To prevent rotation except to full open and full closed — applied to cocks.

Check Valve. — An automatic non-return valve; or a valve which permits a fluid to pass in one direction, but automatically closes when the fluid attempts to pass in the opposite direction.

C.I.F. — A commercial transportation term meaning Cost, Insurance and Freight. It is intended to cover the cost of certain goods at point of destination; an expression of similar usage to F.O.B. but C.I.F. is applied to ocean shipments.

Circular Flange. — A curved or saddle flange.

Circular Weld. — Safe end weld. — A weld extending around a girth seam. Such welds are sometimes butted, but frequently are scarfed.

Clamp. — See Leak, Pipe, Pouring, Service and Water Pipe Clamp.

Clean Out Fitting. — One that is equipped with hand hole and cover so that pipes may be cleaned.

Close Nipple. — One whose length is about twice the length of a standard pipe thread and is without any shoulder.

Close Return Bend. — A short cast or malleable iron U-shaped fitting for uniting two parallel pipes. It differs from the open return bend in having the arms joined together.

Coal Tar. — A by-product of the destructive distillation of soft or bituminous coal.

Coating for Pipe. — Usually a coal tar composition sometimes called asphalt. There are many on the market, such as "Sarco," Mineral Rubber Asphalt, California Asphalt, Trinidad Asphalt, Elaterite, Gilsonite and Dr. Angus Smith's Composition. A well refined coal tar pitch, softening at 60 degrees Fahrenheit and melting about 110 degrees Fahrenheit, is one of the best and most durable coatings known, when properly applied. See Angus Smith Composition, Asphalted, Galvanizing, Kalameined and Smith's Coating.

Cock. — A device for regulating or stopping the flow in a pipe, made by a taper plug that may be rotated in a body having ports corresponding to those in the plug. See Bibb, Bleeder, Corporation, Four-way, Gage, Pet, Plug, and Telegraph Cock.

Coil. — A number of turns of piping or series of connected pipes in rows or layers for the purpose of radiating or absorbing heat.* See Box, Bracket and Expansion Coil.

Cold Drawn. — Drawn cold. — See "Drawn."

Collar. — (1) A term used in place of a coupling in such connections as "Kimberley Collars." (Also used to mean threaded pipe coupling.)

(2) The sleeve in the back of certain styles of flanges, such as a riveted flange, is called a collar.

(3) Again, certain styles of flanges attached by peening and beading are known as "Collar Flanges."

Collar Flange. — One having sufficient collar on its back to allow it to be securely attached to pipe by peening or riveting.

Common Thread. — In machinery, an ordinary standard machine thread, as distinguished from a pipe thread.*

Conduit Pipe. — Wrought pipe used as armor for electric wires.

Converged End. — A term used to signify the beveling in or converging of the ends of certain styles of cylinders, as those used for anhydrous ammonia. Primarily intended to aid in handling by preventing fingers from slipping.

Converse Lock Joint. — A joint for wrought pipe which is made up with a cast iron hub. The joint is made by placing rivets in the ends of the pipe which, in turn, lock in slots in the cast iron hub. The lock is so shaped as to have a wedging action in drawing the pipe tight against a ring in the center of the hub, after which the pipe is leaded in place and calked.

Corporation Cock. — (1) A term usually applied to the cock attached to a street main, owned and operated by or under the supervision of a supply corporation. It is distinct from the more accessible curb cock which is placed in the service line for convenience.

above and below the ground line, in order to prevent corrosion of the pole at the ground line. It is the ordinary name of the "Patent Protecting Sleeve" applied to electric line poles.

Double Bend. — A pipe or fitting shaped like the letter S in outline.

Double Branch Elbow. — A fitting that, in a manner, looks like a tee or as though two elbows had been shaved and then placed together, forming a shape something like the letter Y or a crotch.

Double Extra Strong. — The correct term or name of a certain class of very thick pipe, which is often, less correctly, called double extra heavy pipe.

Double Sweep Tee. — A tee made with easy curves between body and branch, i.e., the center of curve between run and branch lies outside the body. This is in contradistinction to the short fillet between body and branch of standard tees.

Drainage Fittings. — Those that have their interior flush with I.D. of pipe, thereby securing an unobstructed surface for the passage of solid matter.

Drawn. — The term applied to that style of forging by which the thickness is reduced and also, at times, the diameter — by pushing or pulling the material through a die and over a mandrel or plug at the same time. In some cases the mandrel is long and moves at nearly the same speed as the tubes, but in other cases, the mandrel is anchored so as to hold it within the die. When there is no inside mandrel, it is not called drawn product. See Cold and Hot Drawn.

Dresser Joint. — A peculiar form of Normandy Joint. There are various styles.

Drifted. — (1) Having had a drift or short mandrel passed through the pipe in order to be certain that there are no inside irregularities or that they have thereby been removed. It is also, but less correctly, called plugged.

(2) Enlarged by forcing through a tapered mandrel. This meaning of the word is uncommon in the pipe trade.

Drill. — See Pole and Shot Drill.

Drilled. — Used in connection with flanges to indicate that the bolt holes have been made by a drill, i.e., not made by cores.

Drilling Machine. — A name often applied to a tapping machine because many machines drill and tap.

Drive Head. — Protecting end attached to the top of drive pipe and casing, etc. Also called Drive Caps.

Drive Pipe. — A pipe which is driven or forced into a bored hole, to shut off water courses, or prevent caving.

Drive Pipe Joint. — A threaded joint in which the pipe butts in the center of the coupling.

Drive Pipe Ring. — A device for holding drive pipe while being pulled from well. It means nearly the same as elevator but the device is very different.

Drive Shoe. — A protecting end attached to the bottom of drive pipe and casing.

Drop Elbow. — A small sized ell that is frequently used where gas is put into a building. These fittings have wings cast on each side. The wings have small countersunk holes so that they may be fastened by wood screws to ceiling or wall or framing timbers.

Drop Tee. — One having the same peculiar wings as the drop elbow.

Drum. — (1) Package used in shipping fittings and valves.

(2) A short cylinder of large diameter having flat heads, but often used for a cylinder of any style.

Dry Joint. — One made without gasket or packing or smear of any kind, *e.g.*, Ground Joint.

Dry Pipe. — A slotted or perforated steam collecting pipe within a boiler, insuring dryness.*

E

Eccentric Fitting. — One having its openings on center lines that are not concentric, usually arranged so that the interior walls of one side are in one plane. So arranged for draining condensation.

Eckert Joint. — A special design of a form of Armstrong Joint.

Eduction Pipe. — The exhaust pipe from the low pressure cylinder to the condenser.*

Eighth Bend. — (1) A bent pipe whose curved portion deflects the line one-eighth of a circle to ($360°/8 = 45°$).

(2) At times applied to the cast fitting which is more properly called a 45° elbow.

Elbow. — Ell. — A fitting that makes an angle between adjacent pipes. The angle is always 90 degrees, unless other angle is stated.

See Back Outlet, Branch, Double Branch, Drop, Heel Outlet, Reducing Taper, Return, Service, Side Outlet, Street, Three Way and Union Ell.

Elevator. — A device for raising or lowering tubing, casing or drive pipe from or into well. See Casing Elevator.

Ell. — See Elbow.

End. — See Plain and Safe End.

Exhaust Relief Valve. — Nearly the same meaning as a check valve. They are used with condensing engines to allow atmospheric exhaust when condenser is not working. They may be loaded so as to act as back pressure valves.

Expanded End Tube. — Swelled end tube. — These terms are used interchangeably. See Swelled.

Expanded Joint. — A term at times applied to the joint used on casing and which is correctly called "Inserted Joint."

Expansion Coil. — The series or coils of pipe placed in a refrigerating box or brine tank, in which the ammonia vaporizes after passing through an expansion valve.*

Expansion Diaphragm. — An expansion joint of very limited travel which it obtains by buckling the diaphragm. If the diaphragms are corrugated, it is capable of greater motion.

Expansion Joint. — (1) A device used in connecting up long lines of pipe, etc., to permit linear expansion or contraction as the tempera-

ture rises or falls. Usually patterns consist of a sleeve secured to one length of pipe, which works within a stuffing box attached to the next length.*

(2) There are several, such as slip, swing, balanced, diaphragm, loop, swivel, etc. All are intended to accommodate the change in length due to changes in temperature.

Expansion Loop. — Either a bend shaped like the letter "U" or a coil like a "pig tail."

Expansion Pipes. — In cold storage, those pipes within the refrigeration chambers in which the ammonia or other agent changes into a gas under release of pressure, drawing heat in the process from its surroundings.*

Expansion Ring. — A hoop or ring of U section used to join lengths of pipe together so as to permit of expansion, as the well known Bowling hoop for boiler furnace flues.*

Expansion Valve. — (1) A valve used to control flow of ammonia (or other refrigerant). Usually capable of fine adjustment.

(2) The valve of a steam engine that determines the point of cut-off i.e., point at which steam starts to work expansively.

Extension Piece. — Usually a malleable iron nipple with male and female thread.

Extra Heavy. — When applied to pipe means pipe thicker than Standard Pipe; when applied to valves and fittings is to indicate goods suitable for a working pressure of 250 pounds per square inch.

Extra Strong. — The correct term or name of a certain class of pipe, which is heavier than standard pipe and not as heavy as double extra strong pipe. Often less correctly called extra heavy pipe.

F

Faced After. — A term used on flanged work to mean that flanges are faced after they are attached to pipe and that ends of pipe are faced flush with flange, both being at right angles to general axis of pipe.

Faucet. — (1) A device to control the flow of liquid. Originally a hollow plug with a transverse hole in which was placed the spigot. This latter was later bored and equipped with a handle now made in great variety of forms. Commonly called a tap and used in house plumbing to draw water.

(2) Enlarged end of a pipe to receive the spigot end of another pipe, i.e., a bell end.

Ferro Steel. — A special grade of steel that is intermediate in strength between cast iron and cast steel.

Ferrule. — A short piece of steel or copper pipe placed between tubes and tube sheet of boiler. At times they are welded to tube. See Tube Ferrule.

Field Joint. — (1) For poles is made by swaging the inserted end to a uniform taper, about ¼ inch in 18 inches, and then swaging the exterior pipe so that its interior has same taper and size, due allow-

ance being made for shrinkage. It is assembled by placing the two sections accurately in line, but separated a few inches, the lighter section being on rollers. The bell end is then heated by wood fire to a full red heat, and the other end slid in and the whole allowed to cool.

(2) The joint in a pipe line which is made in the field.

Field Tube. — An arrangement of two concentric tubes, which greatly improves the circulation and steaming capacity of a vertical boiler; the heated water rises in the annulus between the inner tube and the exterior heating surface, while the cold water circulates down the inner tube.*

Fire Hydrant. — A hydrant suitable for serving fire hose or engines.

Fire Plug. — See Fire Hydrant.

Fittings. — A term used to denote all those pieces that may be attached to pipes in order to connect them or provide outlets, etc. — except that couplings and valves are not so designated.

See Ammonia, Back Outlet Ell, Branch Ell, Branch Tee, Bull Head Tee, Bushing, Cap, Casing, Clean Out, Cross, Cross Over, Cross Over Tee, Crotch, Double Branch Ell, Double Sweep Tee, Drainage, Drop Elbow, Drop Tee, Eccentric, Elbow, Four-way Tee, H Branch, Heel Outlet Elbow, Increaser, Inverted, Kewanee, Lateral, Long Turn, Manifold, Pipe, Plug, Railing, Reducer, Reducing Taper Elbow, Reducing Tee, Return Bend, Return Elbow, Saddle, Service Ell, Service Tee, Siamese Connection, Side Outlet Ell, Side Outlet Tee, Street Elbow, Tee, Three-way Elbow, Union, Union Ell, Union Tee, Wye, and Yoke.

Flange. — A projecting rim, edge, lip or rib. See Blank, Blanking, Blind, Boiler, Circular, Collar, Curved, Internal, Peened, Pressed, Reinforced Pump Column, Riveted, Rolled Steel, Saddle and Spun Flange.

Flanged. — (1) When applied to a fitting it is used to distinguish from screwed fittings which are always furnished, unless flanges or other style of joint is specified.

(2) When applied to pipe it means fitted with flanges.

Flanged Joint — A joint in pipes made by flanges bolted together.

Flanged Pipe. — Pipe provided with flanges so that the ends can be held together by means of bolts.

Flange Union. — A fitting consisting of a pair of flanges and bolts to connect them for use on threaded pipe. Compare union and lip union.

Flat Head. — (1) Term applied to heads of cylinders meaning that they are neither convex nor concave.

(2) Meaning shape of head when applied to brass or iron cocks.

Flexible Joint. — Any joint between two pipes that permits one of them to be deflected without disturbing the other pipe.

Flue. — A British term used in the same sense as the term "tube" is used in America.

Flue Boiler. — A boiler having smoke flues which pass through the water. When there are many flues of small size the term "tubular boiler" is more usual.

Flue Cleaner. — Tube cleaner. — Frequently a wire brush or soot scraper. At times called a "flue brush."

Flush Bushing. — A fitting intended to reduce the opening of a given fitting by screwing in flush with the face of the fitting.

Flush Joint. — A threaded joint made by turning off nearly half the thickness of the pipe at one end and boring in same manner at the other end, and then threading with a fine thread.

Follower. — A half coupling or lock nut used on a long screw. See Long Screw.

Four-Way Cock. — A cock so designed that the body has four passages and the plug has two passages. It may serve to control the flow of both a supply and exhaust.

Four-Way Tee. — A side outlet tee. (Poor usage.)

Free on Rails. — Signifying that all charges save those of railway transportation are paid by the vender.

Full Way Valve. — (1) A sluice or gate valve for steam, etc., contrived to give a full bore opening of the same area as the pipe.*

(2) Used in error at times to signify a straight way valve.

Full Weight Pipe. — A term used to designate Standard or Card Weight Pipe, which is the Briggs' standard thickness of pipe.

G

Gage. — The main gages used in the pipe trade are threaded plug and ring gages.

Gage Cock. — A small cock in a boiler at water line, to determine the water level.

Gage Length. — (1) The distance gage goes on threaded end of pipe by hand.

(2) Used synonymously for cut lengths.

Gage Ring. — A ring used for gaging the thread on pipe.

Galvanizing. — The process by which the surface of iron and steel is covered with a layer of zinc.

Gasket. — A thin sheet of composition or metal used in making a joint.

Gas Thread. — Briggs' Standard in America; but in England, use is indefinite, though it usually means Whitworth thread on 4 inches and under.

Gate Valve. — A sluice valve; one having two inclined seats between which the valve wedges down in closing, the passage through the valve being in an uninterrupted line from one end to the other, while the valve, when opened, is drawn up into a dome or recess, thus leaving a straight passage the full diameter of the pipe.*

Globe Valve. — A valve having a round, ball-like shell; it is much in use for regulating or controlling the flow of gases or steam.

Go Devil. — (1) A scraper with self-adjusting spring blades, inserted in a pipe line, and carried forward by the fluid pressure, clearing away accumulations of paraffin, etc., from the walls of the pipe.*

(2) In the oil well country this term is applied to a device for exploding the nitroglycerine used to "shoot" an oil well.

Goose Neck. — A return or 180 degree bend having one leg shorter than the other.

Ground Joint. — See Dry Joint.

Grummet or Grommet. — A "cow tail" (frayed end of a piece of rope or twine) smeared with red lead in oil and used about the threads to make a tight joint in British pipe fitting practice.

H

Half Turn Socket. — In oil well drilling, a fishing tool having jaws bent around in an incomplete circle, to embrace lost tools lying against the side of the well.*

Hand Tight. — (1) Tightened by hand with such effort as an average man can continuously exert. It does not refer to such forcing as can be done by a man picked for his strength.

(2) The standard gages are correct as to size when put on hand tight.

Hard Solder. — Brazing Solder. It usually is copper and zinc — half and half by weight. Other alloys are used for special work; frequently, pure copper is used. The usual flux is Borax.

Hazelton Head. — One formed by swaging the end of a pipe nearly to a point, and then welding up the end, either alone or after insertion of rivet or button. The head, when finished, is nearly hemispherical.

H Branch. — In plumbing, a pipe fitting having a branch parallel and close to the main line.*

Head. — See Bumped, Casing, Dished, Drive, Flat, Hazelton, and Patterson Head.

Header. — A large pipe into which one set of boilers are connected by suitable nozzles or tees, or similar large pipes from which a number of smaller ones lead to consuming points. Headers are often used for other purposes, such as heaters or in refrigeration work. Headers are essentially branch pipes with many outlets, which are usually parallel. Largely used for tubes of water tube boilers.

Heel Outlet Elbow. — See Branch Ell.

Horn Socket. — In well boring, an implement to recover lost tools, especially broken drill poles, etc. It consists of a conical socket, the larger end downwards, which slides over the broken part, a spring latch gripping it when entered. Frequently a flaring mouthpiece is riveted to the horn socket, making it a bell mouth socket.*

Hot Drawn. — A term used to signify the product of drawing, when the operation is performed on material that is hot — usually red hot, *e.g.* — hot drawn seamless tubes. The term is sometimes applied to the Mannesmann product that has not been drawn.

Hot Tube. — A tube or pipe lined inside with porcelain, to enable it to withstand firing through without excessive oxidization.*

Hub. — (1) Usually means a cast iron outside ring or collar used to join two pipes.

(2) Bell end of cast iron pipe, or similar end in fitting or valve.

(3) Collar of a flange.

Hydrant. — An outlet placed at or near a main, and provided with a valve to control flow, and with an end suited to attach hose. Those made to serve fire hose, or engines in cold climates, usually have the valve below the frost line, and are so arranged, that when the flow is shut off, the hydrant will drain to prevent freezing up.

Hydraulic Main. — In gas making, the large pipe, partly filled with water, into which the dip pipes discharge the gases, etc., coming from the retorts.*

Hydrostatic Joint. — Used in large water mains, in which sheet lead is forced tightly into the bell of a pipe by means of the hydrostatic pressure of a liquid, preferably tar.*

I

Increaser. — (1) In plumbing, a fitting to join the female end of a small pipe to the male end of a larger pipe.

(2) This is the name applied, at times, to a special type of reducer, whose large end may be a male end for any type of joint and whose small end is always female and tapped for Standard Pipe. (Poor usage.)

Indicator. — A device placed at a valve or fire hydrant and so arranged that it shows whether the valve is open or closed.

Inserted Joint. — The correct name of the joint which at times is called "expanded joint" or "swelled joint." The joints are formed by expanding one end of each pipe so that, when threaded on their interior, they permit screwing in the exteriorly threaded ends that have not been expanded. It is employed mostly on casing.

Internal Feed Pipe. — A pipe perforated at the end, leading the feed water from the check valve opening through the hotter portions of the boiler to the coldest, thus assisting circulation, and gradually introducing the feed water without shock.*

Internal Flange. — A flange that projects from the inner surface toward the center. Used in contradistinction to external flange, which is always meant when the word flange is used without qualification.

Inverted Fitting. — In plumbing, a fitting reversed in order of position — upside down — turned in contrary direction.

J

Jars. — In well boring, a connection between the sinker bars and the poles or cables, made in the form of two links, having a slide on each other of about two feet. The jars permit the tools to fall on the downward stroke, but on the upward jar them, or give them a sharp pull, tending to loosen them from any crevices or cavings that may hold them; a drill jar.*

Joint. — In the pipe trade, applies to the means used to connect pipes to each other or to fittings.

See Ammonia, Armstrong, Artesian, Ball, Bell and Spigot, Block, Bumped, Butted and Strapped, Converse Lock, Corrugated, Cressed

Artesian, Cup, Cup and Ball, Dresser, Drive Pipe, Dry, Eckert, Expanded, Expansion, Field, Flanged, Flexible, Flush, Ground, Hydrostatic, Inserted, Kimberley, Knock-off, Lead, Lead and Rubber, Line Pipe, Matheson, National, Normandy, Peened Flangod, Perkins, Petit's, Pope, Pressure, Riedler, Rust, Shrunk, Siemens, Slip, Socket, Spigot, Swing, Swivel, Thimble, Union, Van Stone, Walker, Welded Flange and Wiped Joints.

Jointer. — (1) A pipe trade term used to express a random length composed of two pieces coupled together. Custom of the pipe trade is that shipments include a small proportion of such lengths.

(2) The term jointer also is applied to very small style of flanges that are suitable for connecting pipes to each other, but not suitable for connecting to fittings.

K

Kalameined. — Coated in a manner similar to galvanizing, but using a composition of lead, tin and antimony.

"*Kewanee.*" — As applied to fittings and valves this word indicates that the "Kewanee" Union principle is involved.

Kewanee Union. — A patented pipe union having one pipe end of brass and the other of malleable iron, with a ring or nut of malleable iron, in which the arrangement and finish of the several parts is such as to provide a non-corrosive ball and socket joint at the junction of the pipe ends, and a non-corrosive connection between the ring and brass pipe end.

Kimberley Joint. — Originally a joint of English manufacture extensively used in the South African Mining District. It consists of an outer wrought sleeve or ring belled out on the ends to form a suitable lead recess for calking, the pipes butting in the center of the sleeve.

Knock Off Joint. — In well drilling, a joint used in the rods of deep well pumps. The jointed ends of the rods are enlarged to a square section and scarfed and notched to fit against one another, and are confined by a clasp or bridle embracing them. The joint is tapered lengthwise and the hole in the clasp is tapered to correspond, so that the tendency is always for the clasp to tighten around the joint.*

L

Laid Length. — (1) The length measured after pipe is placed in position. It is not the same as the "shipped length," which latter is measured over all as shipped, and it is greater than the "cut length," which applies to length of tubular goods only. The laid length includes such items as gaskets or space between ends of pipe in coupling or the insertion of bell and spigot joint or the central ring of C. J. hub.

(2) Laid length is never considered unless order clearly refers to it. To specify it on an order or a drawing always delays execution, unless every essential detail is given.

Lap-weld. — Welded along a scarfed longitudinal seam in which one part is overlapped by the other.

Laterals. — See Wye.

Lead. — The advance made by one turn of a screw. Often confused with pitch of thread, but not the same, unless in the case of a single thread. With a double thread the lead is twice as much as the pitch.

Lead and Rubber Joint. — (1) The ordinary name for any joint in which lead and rubber are employed.

(2) The combination of Matheson Joint and Dresser Clamp is not usually called by this name but acts in the same manner.

Lead Joint. — (1) Generally used to signify the connection between pipes which is made by pouring molten lead into the annular space between a bell and spigot — and then making the lead tight by calking.

(2) Rarely used to mean the joint made by pressing the lead between adjacent pieces as when lead gasket is used between flanges.

Lead Joint Runner. — See Pouring Clamp.

Lead Lined Pipe. — A wrought pipe having a continuous interior lining of lead. When used on flanged pipe the lining is often brought out over the face of the flanges. The lead lining is usually as thick as the same size of lead pipe. It is useful for conducting certain corrosive fluids.

Lead Wool. — A material used in place of melted lead for making pipe joints. It is lead fiber, about as coarse as fine excelsior and when made in a strand it can be calked into the joints making them very solid.

Leak Clamp. — Packing Clamp — Half Dresser Joint. — Usually superposed on some other joint as that made with a coupling.

Line Pipe. — Special brand of pipe that employs recessed and taper thread couplings, and usually greater length of thread than Briggs' Standard. The pipe is also subjected to higher test.

Line Pipe Joint. — The screwed joint used on line pipe.

Lip Union. — (1) A special form of union characterized by the lip that prevents the gasket from being squeezed into the pipe so as to obstruct the flow.

(2) It is a ring union, unless flange is specified.

Lock Nut. — (1) A nut placed on a parallel threaded portion of pipe at a joint in order to stop leaks by means of a grummet, gasket or packing.

(2) Also used to make a joint where the long screw or lock nut nipple has been run through the tank, the lock nuts being used to wedge up against the tank on either side.

Long Length. — A length of pipe greater than can ordinarily be made from one length of plate. The long length is made by uniting two pipes by a circular or safe end weld. Long lengths — less than 40 feet — can be produced in one piece, without weld, by certain processes.

Long Screw. — A short length of pipe having ordinary thread on one end, and the other end threaded for such distance as will allow a lock

nut and a coupling to be screwed by hand without overhanging the end of pipe. It is used in making up connections or joining lines in place.

Long Screw Follower. — A half coupling or lock nut used on a long screw.

Long Turn Fitting. — A term variously employed to mean long sweep, long radius or an angular branch, e.g., a long turn branch may be one whose branch makes about 45° with the run, but end of branch is sharply turned to 90° to run.

Loop. — See Expansion Loop.

M

Male and Female. — (1) Sometimes called recessed; usually written M. & F. It means that one flange of a pair is faced so as to produce a flat, depressed face, extending from inside of pipe nearly to bolt holes. The other flange is faced so as to have a raised portion at same place and only slightly less diameter. The object is to prevent the gasket from blowing out.

(2) Also means Male and Female thread.

Malleable Iron. — Cast iron made from pig iron of the proper kind, so treated as to render it capable of being bent or hammered to a limited extent without breaking, that is, it is malleable. Its strength is above that of cast iron. The treatment is known as annealing.

Mandrel Socket. — A well tool for straightening out the top of casing, etc., within a well, consisting of a lemon-shaped swage within a cone or bell-mouth, by means of which the casing is worked to a circular shape. Also useful for straightening a lost sand pump, etc., so that the dogs may enter.*

Manifold. — (1) A fitting with numerous branches used to convey fluids between a large pipe and several smaller pipes. See Branch Tee.

(2) A header for a coil.

Mannesmann. — A name applied to the product of tube making process, invented by Herr Mannesmann.

Master Die. — A die made standard and used only for reference purposes or for threading taps.

Master Tap. — A tap cut to standard dimensions and used only for reference purposes or for tapping master dies.

Matheson and Dresser Joint. — A combination joint in which a Dresser leak clamp of special form is used to reinforce a Matheson joint. Its special advantage is that it allows repair without shutting off the service pressure. Much used on Natural Gas lines on service pressures up to 250 pounds and at times up to 500 pounds, and on pipes 16 inches outside diameter and less — and even on 20 inches outside diameter.

Matheson Joint. — A wrought pipe joint made by enlarging the one end of the pipe to form a suitable lead recess, similar to the bell end of a cast iron pipe, and which receives the male or spigot end of the next length. Practically the same style of a joint as used for cast iron pipe.

Measurement equals weight. — A commercial transportation term indicating that the specific weight is high enough to secure the freight tariff that is based on weight under steamer's measurement for ocean transit.

Medium Pressure. — When applied to valves and fittings, means good for a working pressure of 125 to 175 pounds per square inch.

Melting Furnace. — A small portable furnace (some designs are mounted on wheels) used for melting lead for lead joint pipe.

Mounted. — When applied to pipe fittings, valves, etc., in such expressions as brass-mounted, nickel-mounted, etc., means having the rubbing or wearing surfaces composed of the material named.

N

National Joint. — A bell and spigot joint whose bell is contracted at its mouth, so as to retain self tightening (U shaped) ring of rubber or other pliable material.

National Pole Socket. — An extension piece for repairing wooden poles that have rotted at ground line. It is a piece of pipe suitably shaped to hold the tapered lower end of upper portion of such pole.

Needle Valve. — At times called a needle point valve. A valve provided with a long tapering point in place of the ordinary valve disc. The tapering point permits fine graduation of the opening.

Nested. — Having one piece placed within another (*i.e.*, telescoped). A thing that is done with pipes and fittings at times, to get a required weight into a given space. See Steamer's Measurements.

Nipple. — (1) A tubular pipe fitting usually threaded on both ends and under 12 inches in length. Pipe over 12 inches long is regarded as cut pipe. See Close, Long Screw, Short, Shoulder, Space, Sub and Swaged Nipple.

(2) Boss or Pop — A thickened or raised place outside or inside of pipe made by welding on a button or pop. It is used on a thin wall when it is desired to tap a hole. These reinforcements are usually flush inside or outside as specified.

Non-Return Valve. — A stop valve whose disc may move independently of the stem so that valve may act as a check. Such valves are largely used between boilers and headers to prevent accidents.

Normandy Joint. — A joint by which the plain ends of two pipes are connected by means of a sleeve whose ends are made tight by rings of packing, compressed between bolting rings and sleeve. There are many similar joints or modifications such as Dayton, Dresser, Hammond, etc.

Nozzle. — (1) A short piece of pipe with a flange on one end and a saddle flange on the other end. May be made of cast iron, cast steel or wrought steel.

(2) A side outlet attached to a pipe by such means as riveting, brazing or welding.

Nut. — See Lock Nut.

O

Offset Pipe. — (1) A pipe bent so as to offset a line, *i.e.*, move the line to a position parallel to, but not in alignment with, balance of the pipe.

(2) A fitting to accomplish the same.

(3) Erroneously used for crossover.

(4) Erroneously used for bend.

(5) Erroneously used for branch pipe.

Open Return Bend. — A short cast or malleable iron U-shaped tube for uniting two parallel pipes. It differs from a close return bend in having the arms separated from each other.

Oval Socket. — In well boring, a fishing tool used to slip over the ends of broken and lost poles, to grip so as to recover them.*

P

Packer. — A device used in an oil or gas well to stop flow in or around the casing or tubing. See Water Packer.

Packing. — (1) A general term relating to yielding material employed to effect a tight joint. A common example is the sheet rubber used for gaskets. The term is also applied to the braided hemp or metallic rings used in some joints, that allow considerable or incessant motion. The British grummet is another example.

(2) Any material used in packing stuffing boxes of valves.

Patterson Head. — One that has the pipe reduced or swaged to about half its diameter and then a flat head welded in.

Peened Flange Joint. — A term used to indicate that the flanges are attached to the pipe by peening — just as welded flange, riveted flange or screwed flange are terms that indicate the method of attachment of flange to pipe. Many designs — or almost any design — can be so attached. The flanges usually depend in part upon beading of pipe at face, although some designs require grooves inside of collar flange, into which grooves the metal is forced by the peening.

Peening. — The act or process of hammering sheet metals with the peen of a hammer, either to straighten them or to impart a desired curvature.*

Penstock. — (1) The conductor between forebay and turbine casing. At times that portion of a forebay that is subject to hydrostatic pressure — used for any type of water wheels.

(2) A railroad term applied to the pipe for supplying water to locomotive tenders.

Perforated. — That in which holes have been bored or pierced. In pipe it is usually accomplished by drilling holes, but the same result can be accomplished cheaply by punching.

Perkins Joint. — One made up with threaded pipe and coupling, both threaded straight (no taper). The one end of the pipe is left square and the other is beveled to a knife edge at mid-thickness. Has been used in Baku oil region.

Pet Cock. — A small cock used to drain a cylinder, fitting, etc. The term means nearly the same as drip or drain cock.

Petit's Joint. — One constructed with a double male and female in which a round rubber is used.

Pilot. — A small valve to operate or relieve pressure on a larger valve.

Pipe. — A long conducting passage, usually a line of tubes; any long tube or hollow body; especially one that is used as a conductor of water or other fluids, as a drain pipe, water pipe, etc.*

See Branch, Breeches, Card Weight, Conduit, Converse Lock Joint, Dip, Double Extra Strong, Drive, Dry, Eduction, Expansion, Extra Strong, Flanged, Full Weight, Internal Feed, Kimberley Joint, Lead Lined, Line, Matheson Joint, Offset, Plug, Reamed and Drifted, Rifled, Riser, Service, Signal, Siphon, Socket, Soil, S, Stand, Standard, Tail, Tin Lined and Tuyere Pipe.

Pipe Bend. — A bent pipe in contradistinction to a bend, which may be a casting. See Bend.

Pipe Bending Machine. — An apparatus by which pipe of any ductile metal may be bent or coiled as desired. Some use rollers and internal mandrels or coils, but the most usual type uses formers and saddles and operates without internal mandrel or fitting. The necessity for internal mandrel or fitting is determined mostly by the ratio of the thickness to the diameter. Where the wall is relatively thin something inside appears obligatory to prevent buckling, crumpling or collapsing.

Pipe Clamp. — A metallic strap or band, made to fit around a pipe, gripping it closely, for the purpose of stopping leaks, etc., a piece of jointing material being usually compressed between the clamp and the pipe.*

Pipe Coupling. — A sleeve or socket of cylindrical form with female threads, which receives the ends of two adjacent pipe lengths.*

Pipe Covering. — A jacket of non-conducting material placed around steam (or other) pipes to prevent loss of heat.

Pipe Cutter. — An instrument for cutting off wrought pipes. A common type is made with a hook-shaped frame on whose stem a slide can be moved by a screw. On the slide or frame one or more cutting discs are mounted, and forced into the metal as the whole appliance is rotated about the pipe.

Pipe Die. — A tool for cutting external threads on pipes. Many types are composite with inserted cutters.

Pipe Dog. — A hand tool that is much used to rotate a pipe whose end is accessible. It is simply a small short steel bar whose end is bent at right angles to the handle, and then quickly returned leaving only enough space between the jaws to slip over the wall of pipe.

Pipe Fittings. — Connections, appliances and adjuncts, designed to be used in connection with pipes, such as elbows and bends to alter the direction of a pipe; tees and crosses to connect a branch with a main; plugs and caps to close an end; bushings, diminishers or reducing sockets to couple two pipes of different dimensions, etc.* See Fittings.

Pipe Grip. — In steam and pipe fitting, an implement consisting of an iron bar with a curved end and provided with a chain of square links to hook on to the jaws of the curved end.* See Chain Tongs.

Pipe Hanger. — A suspension link or band (often split) used to support a pipe without interfering with its expansion and contraction.

Pipe Line. — (1) A line of pipe used for the transporting of liquids or gases.

(2) It has an entirely different meaning from "Line Pipe," which see.

Pipe Roller. — In construction work, these are made of different lengths of wrought pipes to suit the work, and used as rollers for moving heavy articles and machinery.

Pipe Stay. — A pipe hanger — an unusual term.

Pipe Stock. — A holder for dies by means of which threads are cut on pipes by hand.*

Pipe Thread. — A thread employed in connection with wrought pipe. The standard thread is the Briggs', which has an angle of 60 degrees between its sides, slightly rounded at top and bottom, and which has a taper. See Briggs' Standard.

Pipe Tongs. — A hand tool for gripping or rotating pipe. It is frequently made like a large pair of pliers one of whose noses is hook-shaped and the other is made shorter and sharpened so as to dig into the pipe. Chain tongs and pipe wrenches are used for about the same purpose.

Pipe Unions. — Erroneously used, at times, to signify pipe joints.

Pipe Vise. — A special type of vise usually attached to a work bench. It is frequently made with three serrated jaws, one of which moves between the other two and may be forced against the pipe by screw or toggle. At times made with an open or latching side to permit rapid work.

Pipe Wrench. — A wrench whose jaws are usually serrated and arranged to grip with increasing pressure as the handle is pulled. There are many forms such as the Alligator, Stillson, Trimo, etc.

Piping. — In plumbing, steam and gas fitting, the whole system of pipes in a factory, mill or house; the act of laying a pipe system.*

Pitch. — (1) The distance measured on a line parallel to the axis, between two adjacent threads or convolutions of a screw.

(2) The distance between the centers of holes, as of rivet holes in boiler plates.*

Plain End. — Usually contracted to P.E. — Used to signify pipe cut off and not threaded, *i.e.*, ends left as cut.

Plug. — (1) When used without qualification, it always means, in the pipe trade, the ordinary plug or pipe plug that has an exterior pipe thread and a projecting head (usually square), by which it is screwed into the opening of a fitting, etc.

(2) Compare countersunk plug.

(3) The movable part of a tap, cock or faucet.*

(4) Colloquially used for hydrant, penstock, standpipe, water plug, etc. See Socket, Tap, Tube and Water Plug.

Plug Cock. — Usually called a cock. All cocks are essentially plug cocks.

Plug Gage. — A plug or internal gage for measuring inside dimensions.

Plug Pipe. — A short piece of pipe, screwed with a male thread at one end and closed or welded at the other, used as a plug to close another pipe or an opening in a fitting, when a proper plug is not obtainable.*

Plug Tap. — A tap with threaded portion straight or without lead, used for bottoming.

Pole Drill. — In well boring, a system where a rigid connection is used between the drilling tools and the reciprocating beam.*

Pop. — (1) A spring loaded safety valve.

(2) A boss or nipple cast on a fitting or welded to a pipe.

Pope Joint. — A joint very similar to the Van Stone. In one form the flange is separately formed and welded to the pipe.

Pouring Clamp. — Lead Joint Runner — Some forms are made of metal, others of rubber and others of asbestos. The commonest makeshift is a piece of frayed rope smeared with clay. All styles serve to guide the lead into space provided for it in lead joint pipe.

Pressed Flange. — Usually signifies a light style of flange, made from plate steel by press forging or forming. When the flange is so made of heavy stock, whose thickness is changed by the forging, it is better to call the product Press Forged. Some flanges are Press Forged part way and then rolled. See Rolled Flanges.

Pressed Forged. — A term used to indicate the operation of forming by steady pressure as distinguished from forging by hammering or rolling or drawing. The distinction between "Press Forging" and "Press Forming" is that the former changes the thickness or section materially, while the latter only changes the form and may incidentally change the section or thickness.

Pressure Joint. — A term used by British trade to signify that the threads of both pipe and coupling are tapered. It closely corresponds to American joints used on Line Pipe, Casing or Tubing, etc.

Protector. — A ring threaded on its inside and used to protect threaded end of pipe during transit.

Pump Column Flange. — See Reinforced Pump Column Flange.

R

Radiator. — That which radiates or sends forth heat, as by a coil of steam or hot water heating pipes.

Radiator Valve. — An angle valve such as is fitted to a steam or hot water heating radiator.

Radius of Bend. — (1) The distance measured always from the center of curvature to the center of the pipe or fitting. The relation between length of radius and size of pipe is modified by the ratio of the pipe's thickness to its diameter; in general the thinner the pipe the longer the radius.

(2) The radial distance from the center line of a fitting to the center of curvature, about which the body of a fitting is struck or swept.

Railing Fittings. — Those used on hand rails. There are various styles. To the trade, rail fittings are understood to be globe shaped in the body, with ends reduced to take thread.

Raised Face. — A term used to indicate that flanges are faced 1/32 inch or so higher inside of the bolt circle.

Random Length. — The "catch length" or length of good quality pipe, made from any piece of plate skelp after its ends have been trimmed. For Butt and Lap Weld pipes usually about 20 feet or less.

Reamed. — In pipe trade, means having the burr from cutting off tool removed from inside, at ends, by a slight countersinking.

Reamed and Drifted. — Usually contracted to R. & D. See the separate terms.

Receiver Filling Valve. — A valve of peculiar construction for the admission of compressed gas to the receiver, so that it can be transmitted to the regulator for consumption.

Recessed. — (1) Counterbored for a short distance when applied to couplings.

(2) Counterbored or provided at back with a calking recess when applied to flanges.

(3) Erroneously applied, at times, to flanges to mean M. & F. to distinguish them from T. & G. or P. F.

Reducer. — (1) A fitting having a larger size at one end than at the other. Some have tried to establish the term "increaser" — thinking of direction of flow, but this has arisen from a misunderstanding of the trade custom of always giving the largest size of run of a fitting first; hence, all fittings having more than one size are reducers. They are always inside thread, unless specified flanged or for some special joint.

(2) Threaded type is made with abrupt reduction.

(3) Flanged pattern has taper body.

(4) Flanged eccentric pattern has taper body, but flanges at 90 degrees to one side of body.

(5) Misapplied at times, to a reducing coupling.

Reducing Taper Elbow. — A reducing elbow whose curved body uniformly decreases in diameter toward the small end.

Reducing Tee. — Any tee having two different sizes of openings. It may reduce on the run or branch.

Reducing Valve. — (1) A spring or lever loaded valve similar to a safety valve, whereby a lower and constant pressure may be maintained beyond the valve.

(2) A valve for reducing the pressure of air admitted to a train signal pipe below that maintained in the brake pipe and main reservoir.

Reflux Valve. — In hydraulics, a flap valve used for the purpose of taking off the pressure of a head of water acting in a backward direction against a set of pumps.*

Reinforced Pump Column Flange. — A flange that is secured to, or fastened to, pipe by rivets in addition to being peened and beaded.

Reservoir. — An incorrectly used term to denote a cylinder.

Sherardizing. — A process in which clean surface of iron or steel is coated with a zinc-iron alloy to protect against rust.

Shoe. — See Casing and Drive Shoe.

Short Nipple. — One whose length is a little greater than that of two threaded lengths or somewhat longer than a close nipple. It always has some unthreaded shoulder between the two threads.

Shot Drill. — An earth boring drill using shot as an abrasive, somewhat after the manner of a diamond drill.*

Shoulder Nipple. — A nipple of any length, which has a shoulder of pipe between two pipe threads. As generally used, however, it is a nipple about half way between the length of a close nipple and a short nipple.

Shrunk Joint. — (1) A joint secured in place by shrinking a larger pipe on a smaller one.

(2) A term at times applied to a form of collar flange that is attached by shrinking the flange on the pipe and then expanding the pipe to a trumpet mouth. This expanded mouth is its distinctive feature.

Siamese Connection. — A crotch fitting, usually arranged with union inlets for fire hose.

Side Outlet Ell. — An ell with an outlet at right angles to plane of run.

Side Outlet Tee. — The same as four-way tee.

Siemens Joint. — One for high pressure hydraulic work designed by Dr. Siemens. It is extensively employed on the steam chests of locomotives. Its essential feature is a soft copper wire in a groove.

Signal Pipe. — (1) Pipe made to the Signal Association Standard as to size, thread, coupling, weight, etc., but not equipped with plugs and rivets.

(2) Special pipe used on interlocking switches and their signals on railroads. It has a peculiar joint, that is both threaded and connected by a plug riveted to the pipe.

Signal Thread. — The thread used on Signal Pipe. Usually longer than Briggs' Standard and of less taper.

Sinker Bar. — A heavy bar of round iron which goes to make up the weight in a string of well boring tools. The sinker connects the drill bit with the jars, and is sometimes made in two lengths on account of easy handling; in such a case, the upper half is sometimes known as the sinker and the lower part as the auger stem.*

Siphon. — (1) A pipe bent in the form of U or ∩ acting on the principle of the hydrostatic balance so that the pressure of water in one leg always tends to equalize that in the other.

(2) A bent tube or pipe with limbs of unequal length for transferring liquids from a barrel or other receptacle. The action of the instrument is due to the difference in weight of the liquid in the two legs.

(3) A U shaped tube fitted to steam gages, etc., so that nothing but water shall enter the gage.

(4) In railways, the curved pipe of gradually increasing section which leads from a water scoop into the tender.*

Siphon Pipe. — A bent tube with unequal limbs by means of which liquids are drawn from a vessel; the shortest limb being placed in the liquid to be drawn off; it is set in action by exhausting the air from the longer.*

Skelp. — A piece of plate prepared by forming and bending, ready for welding into a pipe. Flat plates when used for butt-weld pipe are called skelp.

Sleeve. — A coupling, collar or hub — Also a special form of Converse Joint Hub that omits the central ring and permits the rivets to pass clear through. See River Sleeve.

Slip Joint. — An inserted joint in which the end of one pipe is slipped into the flared or swaged end of an adjacent pipe. The two pipes are often soldered together.

Smith's Coating. — Dr. Angus — See Angus Smith.

Socket. — (1) A recess or piece furnished with a recess, into which some other piece may be inserted and securely held; as, a socket in the ground for the reception of a post or pole.*

(2) The British term for what is called a coupling in America.

(3) The enlarged and recessed end of a cast iron pipe into which the opposite end of another pipe is inserted. See Half Turn, Horn, Mandrel, National Pole, Oval and Wide Mouth Sockets.

Socket Coupling. — British term for what is known in America as a coupling.

Socket Iron. — A bar from which pipe couplings are made.

Socket Joint. — The British equivalent of the American term Coupling Joint.

Socket Pipe. — In pipe fitting, a cast iron pipe which is provided with a socket at one end and a spigot at the other. The sockets of wrought pipes are couplings, and are screwed over the ends on the outside diameter.*

Socket Plug. — In steam fitting, a plug for stopping the ends of pipes or openings in pipe fittings. It differs from the ordinary plug, in that it is provided with a recess into which a wrench fits.

Soft Solder. — Tin and lead alloy. The first grade is half and half by weight, which melts at a lower temperature than either lead or tin.

Soil Pipe. — In plumbing, a pipe which conveys away the waste from water closets, etc., usually made of cast iron.

Solder. — An alloy used for connecting two pieces that are less easily melted. See Hard and Soft Solder.

Space Nipple. — A nipple with a shoulder between the two threads. It may be of any length long enough to allow a shoulder.

Special Product. — Not Standard. Also used to mean a product that is not made to any of the regular lists of goods.

Spellerizing. — The method of treating metal, which consists in subjecting the heated bloom to the action of rolls having regularly shaped projections on their working surfaces, then subjecting the bloom to the action of smooth faced rolls, and repeating the operation, whereby the surface of the metal is worked to produce a uni-

formly dense texture, better adapted to resist corrosion, especially in the form of pitting.

Spigot. — (1) The end of a pipe, fitting or valve that is inserted into the bell end.

(2) The tapered male part of an inserted joint, as in plumbers' wiped joint.*

(3) A cock, tap or faucet used to draw water, etc.

Spigot Joint. — A pipe joint made by tapering down the end of one piece and inserting it into a correspondingly widened opening in the end of another piece. Also called faucet joint (unusual).

Spinning. — The operation of changing the shape of a rapidly revolving plate or tube by the action of a spinning tool. In light work the tool is usually similar to a burnishing point, but on heavy work a wheel or revolving head is often used. At times the work is stationary and the tool moves. The product is called "Spun Work." — See Spun Flange.

S Pipe. — In pipe fitting, a pipe whose outline is roughly that of the letter S, used for connecting parallel lengths of straight piping. Also called offset elbow or offset bend.*

Spot Faced. — A term used to indicate that an annular facing has been made about a bolt hole, to allow a nut or head to seat evenly.

Spring. — A pipe bent to a small angle. (Poor usage.)

Spud. — (1) Oil Well Fishing Tool. In well boring, a tool shaped like a spade, for freeing lost or broken tools by digging around them.*

(2) A bushing or coupling, by which the hole of a sink or water cooler drip is connected with the drain or drain pipe.

Spun Flange. — A flange formed from the material of the pipe by spinning. *e. g.* — A Van Stone flange may be made by press forming, peening, or by spinning.

Squib. — A detonator; in well boring, a vessel containing the explosive and fitted with a time fuse which is lowered down a well to detonate the nitroglycerin used to torpedo it.*

Standard Pipe. — (1) The standard adopted by the Wrought Pipe makers in 1886. The Briggs' standard runs to 10 inch size inclusive, and by extension the pipe sizes embrace the nominal sizes 11–12–13–14 and 15 inches. For the 11 and 12 inch sizes the outside diameters are 11.75 and 12.75 inches, while for 13–14 and 15 inches the outside diameters are one inch larger than the nominal diameter. By later agreement 9 inch size was changed from Briggs' size to 9.625 inches outside diameter. The thickness of all sizes 10 inches and under is determined by Briggs' rule; above 10 inches it is 0.375 inch thick.

(2) Standard is a term frequently but unfortunately used to indicate a regular or common product.

Standard Pressure. — A term applied to valves and fittings good for a working steam pressure of 125 pounds per square inch.

Stand Pipe. — (1) In hot water heating, an upright pipe having its top connected to the expansion tank to afford room for expansion.

(2) A vertical pipe arrangement, often of great size, at pumping stations into which water is pumped.*

Stay. — (1) In the pipe trade, stay tube or upset tube.

(2) A bolt from tube sheet to tube sheet. This is also called a longitudinal or through stay.

(3) In boilers there are many different kinds of stays used, at times, and their special names amply describe them, as crown, diagonal, radial, girder gusset sling, cross, bolt, etc. See Tube Sheet Stay.

Stay Tube. — A boiler tube, stouter than the others, which is threaded at each end and screwed through both tube plates to brace them together. The ends are either beaded over, or else secured with lock nuts. The threads are usually plus and minus; that is, the thread at the front is larger than the outside diameter of the tube, while that at back is the same diameter as the tube. Upset tubes are often used as stays.*

Steam Coupling. — The word steam, when used in such phrase, means that the coupling is threaded to suit Standard Pipe.

Steamer's Measurement. — The cubic space obtained from the greatest width, length and height; used in determining ocean freight which is based on 56 pounds = one cubic foot, or 40 cubic feet = one ton (2240 pounds).

Stiefel Process. — A parallel process to Mannesmann or a modification thereof — The product is seamless tubes or pipe.

Stove. — Stoved — Upset.

Straight Way. — (1) A term applied to valves to signify that the fluid passes through without deviation. Such valves offer the least resistance to flow, and permit the passage of such tools as "Go Devils."

(2) Full bore, straight flow, full way, full area are terms that at times have been proposed to signify the same thing.

Street Elbow. — Service Ell.

Strum. — A strainer, or the like, to prevent the entrance of solid matter into a pump chamber or suction pipe.

Sub Nipple. — Substitute nipple; that is, a short piece of pipe having different styles of thread on its ends.

Sucker Rod. — In bored or drilled wells, the jointed pump rod, which carries the bucket at its lower end, and is actuated by the walking beam at its upper.*

Swaged. — Reduced in diameter by use of blacksmith's swages or swedges, hence the name. This is a hammering process, but the same result may be attained by press forging or spinning.

Swaged Nipple. — A nipple that has one end smaller than the other; a reducing nipple.

Sweated. — A term used synonymously with tinned, that is, coated with soft solder or tin. It is usual in making sweated joints on pipe to sweat both the pipe and the fitting or socket separately before sweating them assembled.

Sweep. — A term used to convey the idea that the curvature is not abrupt: — *i.e.*, that the flow may take place easily and without the formation of eddies.

Swelled. — Enlarged. Swelled end tubes usually have their ends enlarged for a short distance. Also see Inserted Joint.

Swing Joint. — One made like a cock, except with only one outlet in the body, and another outlet from the plug at right angle to axis of plug.

Switch Valve. — A device for conducting exhaust steam into the smoke-stack or atmosphere. A three-way cock.*

Swivel. — (1) In oil well drilling, a short piece of casing having one end belled over a heavy ring, then a large hole through both walls, the other end being threaded.

(2) Any device that prevents longitudinal motion but allows axial rotation. See Water Swivel.

Swivel Joint. — One that rotates about an axis without decreasing its efficiency as a joint.

Symbols. — See Abbreviations.

T

Tail Pipe. — The suction pipe of a pump. It communicates with the pump stock through a clack or check valve, and in the case of metal pumps is in two parts, the upper one of which has a screw thread at its lower end, by which it is secured to the lower part, the latter being cut to a suitable length.*

Tank. — Often applied to a cylinder having closed ends. (Poor usage.)

Tap. — A tool used for cutting internal threads. Small sizes are usually made solid, but larger sizes are often made with inserted cutters, so that they can be withdrawn from the work, without stopping, when the desired threads are cut. See Master and Plug Tap.

Tapped. — (1) The operation of making an internal thread by means of taps.

(2) Often used loosely, to mean chased or threaded.

(3) In the pipe trade it means threaded regardless of the method of production.

Tapping Machine. — A machine for cutting and tapping a small hole in a pipe (as a street main), that is either empty or carrying pressure. Two classes of tapping machines are made, designated as "pressure" and "dry" tapping machines. They are sometimes called drilling machines.

Tee. — A fitting, either cast or wrought, that has one side outlet at right angles to the run. A single outlet branch pipe. See Branch, Bull Head, Cross-over, Double Sweep, Drop, Four-way, Reducing, Service, Side Outlet and Union Tee.

Telegraph Cock or Faucet. — A self-closing cock, the lever of which resembles the key of a telegraph instrument. When the water enters the cocks horizontally they are called horizontal telegraph cocks, when it enters vertically they are called vertical telegraph cocks.

Telescoped. — (1) When one pipe is slid inside of another, it is said to be telescoped. When the term telescoped is applied to pipe, it means

that two pipes have been separately made, and then telescoped, and then welded together so as to form one pipe. This is usually done so perfectly that it is difficult to see the weld, except by special or destructive treatment.

(2) Nested (poor usage).

Temper Screw. — Part of a drilling rig used to regulate the force of blow of the drill bit.

Templet. — (1) A gage ring for thread.

(2) A drilling jig for holes in flanges.

Thimble. — See Boiler Thimble.

Thimble Joint. — A sleeve joint packed to allow longitudinal expansion. A slip expansion joint.

Threads. — See Ammonia Cock, Briggs', Common, Gas, Pipe, Sellers, Signal, V, Vanishing, Whitworth and Wine Bore Threads.

Three Way Elbow. — A double branch elbow (poor usage).

Tin Lined Pipe. — A wrought pipe lined with block tin. Tin lining of lead pipe was introduced by Anderson in 1804.

Tongs. — See Chain Tongs, Pipe Grip, Pipe Tongs and Pipe Wrench.

Tong Tight. — An expression used to indicate that coupling, flange or joint has been tightened by tongs, frequently in a threading machine.

Tongue and Groove. — Usually applied to flange connections by forming a tongue on one flange and a groove on the other flange. Usually placed about midway between bolts and inside diameter of pipe. The gasket is placed in the groove. The male dimensions should be equal to the depth of the groove. The depth of the groove should equal the thickness of the gasket plus 1/16 inch.

Trailing Water. — The operation of drawing water a long distance through pipes, by means of suction. As long as the total height lifted, plus the friction in the pipe, does not exceed a head of 25 to 26 feet, water can be trailed a very great distance. The only difficulty is possible leakage at the pipe joints, which impairs the vacuum.*

Tube. — (1) In America, means a boiler tube whose outside diameter is its nominal size. In England, tubes mean tubular goods, whether tubes, pipe or casing.

(2) In a steam boiler, the pipes, tubes, or flues employed for conducting the products of combustion from the fire box to the chimney, taking heat from them during their passage and transferring it to the water in the boiler. The tubes are fitted into holes in the tube sheet at each end of the boiler, being expanded or beaded therein, or occasionally fastened with a copper or iron ferrule. The tubes of water tube boilers usually extend between headers, legs, or drums, into which they are secured as into tube sheets, but the tubes may be made with closed ends, and circulation secured by special devices. In water tube boilers, the water is inside the tubes and the hot gases outside. See Annealed End, Beaded, Boiler, Brick Arch, Cross, Expanded End, Field, Hot, Ribbed and Stay Tubes.

Tube Cleaner. — (1) A stiff wire brush or metallic scraper attached to the end of a rod and used to remove soot or scale from boiler tubes.

(2) A steam jet may serve for tubes through which the furnace gases pass.

(3) Some cleaners for removing hard scale from the interior of tubes are highly ingenious pieces of mechanism.

Tube Expander. — A tool for expanding boiler tubes within the tube sheet, causing them to hold firmly. A center piece is fitted with cylindrical rollers, and inserted within the tube end. A long taper pin is placed between the rollers and rotated; as it revolves, it turns the rollers around and forces the material of the tube into a tiny ridge on each side of the plate, thus gripping it and preventing leaks.*

Tube Ferrule. — A ring of hard wood, used for holding condenser tubes to their plates. The ferrule fits between the outside of the tube and the hole in the plate, and being swelled by the action of the water, renders the tubes water-tight.*

Tube Packing. — A bag of flaxseed, or ring of rubber made to occupy the space between the tube of an oil well and the bored hole, to prevent access of water to the oil bearing stratum.*

Tube Plug. — A tube stopper, to be used in case of leak of a boiler tube. It usually consists of a double wooden plug with a smaller central part. The plug is forced into the tube until the small part is opposite the leak; the plug is then in equilibrium and will not blow out, while the wood rapidly expands and fills the tube. This device is rarely used, a special stopper being more frequently applied in cases of emergency, or the tubes are cut off altogether, when conditions permit, by means of a disc on either tube plate, held together by a through stay.*

Tube Scaler. — A tool for removing scale and other incrustation from the inside of steam boilers. See Tube Cleaner.

Tube Scraper. — An instrument or appliance for removing soot and ashes from the interior of boiler tubes.*

Tube Sheet. — One of the sheets of a boiler, condenser, etc., which is drilled with holes for the reception and support of the tubes. Each sheet is defined according to its position; as, fire box tube sheet, middle condenser tube sheet, etc.

Tube Sheet Cutter. — A trepanning tool, having a spindle guided by a central hole, while a cranked tool cuts out a disc, corresponding to the hole required for the reception of a boiler tube.

Tube Sheet Stay. — A rod extending through a boiler from tube sheet to tube sheet, and having heads or nuts on the exterior of the sheets. It ties the tube sheets together so as to prevent disruption by steam pressure. Another form of stay is riveted to the shell and to the tube sheet. See also Stay, Stay Tube and Upset.

Tubing. — A special grade of high test pipe fitted with threads and couplings of special design. Tubing is made to the same outside diameters as Standard Pipe. It is similar to what is known in Europe as hydraulic pressure pipe.

Tubing Catcher. — A device to prevent tubing from slipping back into an oil well when it is being pulled.

Tuyere. — (1) Tuyere pipe is the name applied to pipe of special quality. It is used in making tuyere coolers, cinder monkeys, etc. It is only made in small sizes.

(2) The name of the nozzle used where a blast of air is forced into a furnace of fire such as that used by blacksmiths.

U

Under Reamer. — An oil well tool used for enlarging the hole below a drive shoe, etc.

Union. — (1) The usual trade term for a device used to connect pipes. It commonly consists of three pieces which are, first, the thread end fitted with exterior and interior threads, second, the bottom end fitted with interior threads and a small exterior shoulder and third, the ring which has an inside flange at one end while the other end has an inside thread like that on the exterior of the thread end. In use a gasket is placed between the thread and bottom ends which are drawn together by the ring. Unions are very extensively used because they permit connecting with little disturbance of the pipe positions.

(2) The Kewanee Union is made with the thread end of brass, and the thread and bottom ends are ground together so that no gasket is required.

(3) The act of joining or uniting two or more things. The joint or connection thereby made. Rarely used in this sense in the pipe trade.

(4) There are many types of unions. See Boyle, Flange, Kewanee, Lip, Pipe and Ring Union.

Union Coupling. — A term sometimes applied to a right and left handed turn buckle, or sleeve nut, whereby two parts might be connected and drawn together without turning anything but the coupling.*

Union Ell. — An ell with a male or female union at one end.

Union Joint. — A pipe coupling usually threaded which permits disconnection without disturbing other sections.*

Union Tee. — A tee with male or female union at connection on one end of run.

Upset. — The product of any cold or hot forming of material in which the metal is thickened by being forced back into itself. It is usually done at a red heat by hammering or press forging. Upset tubes are those whose ends have their walls so thickened for a short distance; usually to such extent that the threading leaves as great a thickness of metal below roots of threads as in main body of tubes. Upset tubes are much used as stay tubes; they are sometimes called stoved tubes.

V

Valve. — A device used for regulating or stopping flow in a pipe, etc. The form that allows an opening the full inside diameter of the pipe is usually known as a Gate Valve or Straight Way Valve. The same result is obtained in some forms of cocks. The essent

difference between a valve and a cock is that the closure of the latter is invariably accomplished by rotating a taper plug, which has ports or holes in it that correspond to holes in the body. See Angle, Angle Gate, Back Pressure, Bracket, Butterfly, By-pass, Check, Cross, Exhaust Relief, Expansion, Fullway, Gate, Globe, Needle, Non-return, Pop, Radiator, Receiver Filling, Reducing, Reflux, Screw Down, Straight Way, Switch, Wedge Gate, and Wheel Valve.

Valve Box. — A pipe placed over a buried valve to allow access to the valve stem or wheel for opening or closing. The top of the pipe is usually closed by a plate or cap to exclude dirt, that would interfere with operation. There are many designs, the most usual being adjustable within limited range, to suit the depth planted, and are called Extension Valve Boxes, Street Boxes or Service Boxes.

Valve Seat. — A flat or conical fixed surface on which a valve rests, or against which it presses.

Valve Stem. — A rod attached to a valve by which the latter is moved; it is also called a valve spindle.

Vanishing Thread. — A pipe so threaded that the reaming or countersinking of the coupling is at the same angle as the lead of the dies that thread the pipe. The pipe is so threaded that the taper comes into contact at same time as the threads tighten. The term "Vanishing" comes from the peculiar bore of coupling.

Van Stone Joint. — A flanged joint, in which the pipe itself is flanged out over the face of the bolting ring.

V Thread. — (1) A screw thread formed by means of a sharp pointed tool, as contrasted with a square thread.

(2) A standard thread for pipes, tubing, etc., with an angle of 60 degrees between the sides.* See Briggs' Standard.

V Welding. — In boiler making, a mode of welding the plates of boiler flues in which there is neither butt nor lap properly so called, but in which a strip of square rod is inserted angle ways between the nearly abutting edges of the plate, so that it unites the edges upon two sides of the rod.*

W

Walker Joint. — One form of a flexible joint that is made with spherical mating surfaces, and which permits a few degrees flexure in any direction.

Water Arch. — (1) In a steam boiler, a chamber of plates or of pipes within a furnace, replacing the ordinary fire brick bridge, or arch, or the deflecting arch over the firedoor of externally fired boilers. The same as water table.

(2) A locomotive fire box arch, suspended by tubes, which adds to the heating surface and promotes circulation.*

Water Bar. — A tube serving as a fire bar in a water grate.*

Water Column. — A special fitting connected to a boiler above and below the water line. To it are usually connected the water gage and gage cocks.

Water Flush. — A system of well boring, in which percussive drills are used in connection with water forced down to the bottom of the hole through the drill rods. This water jet makes the tools cut better, and washes the detritus up out of the hole. Its great objections are, the great probability of waterlogging the surrounding territory, and the pressure of water forcing back bodies of oil, which have only a small force behind them, thus leading to the passing by of possibly valuable oil-bearing territory.*

Water Gage. — A glass pipe connected to a boiler above and below water line so as to see the water level.

Water Grate. — When, as in certain steam boilers, to increase the heating surface, hollow water tubes are used for grate bars, the arrangement is termed a water grate.*

Water Hammer. — The shock or blow struck by water whose flow in a pipe is suddenly arrested, *e.g.*, sudden closure of a faucet often causes shocks that so shake the pipes that a clanking noise is produced. The term is more used in connection with steam piping, where the condensed steam (water) is forced ahead by the steam rushing into a cold empty pipe with such high velocity, that it slams the water against bends, elbows, valves, etc., with terrific force or shock. It is peculiarly violent when steam is admitted suddenly to a cold vacuous pipe, because there is no air to cushion the blow; but even air will not ordinarily eliminate its destructive and dangerous violence. The main remedies are easy bends and slow closure of the valve for liquids, and for vapors (steam, etc.), slow admission until all pipes are brought to temperature.

Water Packer. — A device intended to cut off water from the lower levels of an oil well, or to separate two distinct flows of oil from different strata; more especially in fountaining wells. It consists essentially of two tubes sliding within one another, the inner tube being swathed with rubber rings or with canvas and rope yarn, for some length between its own upper socket and the socket on top of the larger tube. The whole is lowered into the well, on the tubing, until the perforated anchor pipe, connected with the outer tube, rests on the bottom. The whole weight of the string of tubing then rests upon the inner tube of the packer, compressing the packing outward against the casing of the well, so that the upper strata are cut off from communication with the lower.*

Water Pipe Clamps. — A term used to indicate service clamps (poor usage).

Water Plug. — It means stand pipe or penstock, or hydrant. Water plug is the more general colloquial term used on railroads.

Water Swivel. — In well boring, a combined universal joint and hose coupling, forming the connection between the water supply pipe and the drill rods, and permitting complete rotation of the tools.*

Water Tube Boiler. — A steam boiler in which the boiler tubes contain water. Used in contradistinction to the older type of boiler, in which the tubes were used as flues and surrounded by water.

Wedge Gate Valve. — A gate valve having inclined seats; usually a wedge - shaped disc is pressed down between these inclined seats.

Weight. — A term that by trade custom has come to be frequently attached to various tubular products. It has grown out of the need in the trade for several thicknesses of the same outside diameter and the practice of determining the thickness by the average weight per foot. See Card and Full Weight.

Weld. — See Butt, Circular, Lap, Safe End, Scarf and V Weld.

Welded Flange Joint. — A joint made by flanges attached to pipe by welding; for this it is necessary that material of flange be capable of being welded (*e.g.*, soft steel or wrought iron). The best known style is made by slipping the end of pipe through the flange ring forgings, and then bringing all to a welding heat and hammering or pressing together. Another style uses a collar on the flange; the collar is attached to flange by a circular or safe end weld.

Wheel Valve. — A stop or gate valve opened by means of a hand wheel and screw, as distinguished from those patterns of gate valves in which the valves are opened or closed quickly by means of levers, or the many types of butterfly and other throttle valves.*

Whitworth Thread. — The standard thread for screws, employed in England and her colonies, and on the European Continent. The angle of the thread is 55 degrees, one-sixth being rounded off at top and bottom.*

Widemouth Socket. — A well borer's fishing tool, in which the socket is fitted with a bellmouth, nearly the full bore of the casing, thus making it easy to grip the ends of broken poles or the like, when lost at the bottom of a well.*

Wine Bore. — A term used to indicate standard pipe thread (rare and poor usage).

Wiped Joint. — A lead joint in which the molten solder is poured upon the desired place, after scraping and fitting the parts together, and the joint is wiped up by hand with a moleskin or cloth pad while the metal is in a plastic condition; it makes a neat and reliable connection in the pipe.*

Working Barrel. — The body of a pump used in oil wells.

Wye. — Y. — A fitting either cast or wrought that has one side outlet at any angle other than 90 degrees. Usually set 45 degrees, and always so set unless angle is specified. It is usually indicated by letter "Y."

Y

Y. — *Wye.* — Which see.

Y Base. — The same as a crotch or back outlet return bend, except that the horns are parallel.

Y Bend. — Y. — Wye.

Y Branch. — (1) A wye.

(2) Sometimes used to designate a fitting whose shape is nearly like that of a single sweep tee.

Yoke. — (1) In a rising stem valve, the portion of the bonnet that supports the nut, hand wheel, etc.

(2) A pipe with two branches; as, for hot and cold water, uniting them to form one stream.*

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